IBM - Federal Systems Division
Gaithersburg, Maryland 20760

Cambridge Advanced Systems
Computer Control Department
Cambridge, Massachusetts 02138

SWITCH Program Documentation

by:

E. F. Harrold and K. R. Brown

Interim Report Under Contract No. NAS 8-21315
for the period 3/8/69 to 3/8/70

Dated:

1 May 1970

Prepared for:

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 35812

SWITCH PROGRAM DOCUMENTATION

CONTENTS

INTRODUCTION

This report describes the digital computer program SWITCH, which has been developed for optimization of multiple-burn vacuum rocket flights. The analysis upon which this algorithm is based is described in reference [1] and only the equations actually implemented will be described here. The report will consist of a description of each subroutine used in the algorithm as well as a users guide.

The SWITCH algorithm is an application of a shooting method to a two-point boundary value problem of trajectory optimization. The method involves guessing initial costate and switching times (separating burn arcs from coasting arcs) and propagating state and costate and their partial derivatives with respect to initial costate and the switching times over a complete trajectory. The partial derivatives are then used to obtain a Newton Raphson adjustment of the initial costate and switching times.

RESTRICTIONS

The program generates trajectories consisting of alternating coast and burn arcs. The first arc may be either a coast or a burn but the last arc must always be a burn. All arcs of the trajectories are assumed to be positive in time with the exception of an initial coast arc which is allowed to be positive or negative in duration (allows starting the first burn at any position along initial orbit). The number of burn and coast

---

[1] K. R. Brown, E. F. Harrold, and G. W. Johnson. "Rapid Optimization of Multiple-Burn Rocket Flights," NASA Contractors Report CR-1430, September, 1969.

arcs may vary with a maximum of six separate arcs. Discrete changes in vehicle mass are allowed only at the start of coasting arcs, and all coasting arcs are assumed to have negative orbital energy (elliptical).

The algorithm consists of five basic parts: the input and output routines (MAIN and OUT), the supervisory routine (SWITCH), the burn routines (RKG031, RKSTEP, and YDDRHS), the coast routines (COAST and AMULT) and the boundary value and linear algebra routines (ADJUST, BVEVAL, and SOLVE).

SUBPROGRAMS

1. MAIN (Input Routine)

This routine is presented as a sample input routine. All of the data necessary to define a case is collected in this routine. The following table defines the input variables in order with FORTRAN read formats:

TABLE I - INPUT VARIABLES

CARD	VARIABLES	FORMAT
1	NCASE	I2
2		
3	PLANS (54)	18A4
4		
5	uk, AMASS, HMAX	3F10.1
6	XOE(I) (I = 1,6)	6F10.1
7	QOE(I) (I = 1,6)	6F10.1
8	C(I) (I = 1,7)	7F10.1
9	LEGMAX, ITMAX	2I2
10	ATP(1,1); ATP(1,2); ATP(1,3); ATP(1,4)	4F10.1
11	ATP(2,1); ATP(2,2); ATP(2,3); ATP(2,4)	4F10.1
.		
.		
.		
10 + L	ATP(L,1); ATP(L,2); ...ATP(L,4)	4F10.1
	(L = LEGMAX + 1)	

CARDS 2 - 10 + L are repeated for each data case.

The variables are defined on the following page. The main routine also prints the input quantities and initiates a case by calling the SWITCH subroutine.

VARIABLE NAME	SYMBOL	VARIABLE DESCRIPTION
1) NCASE		Number of cases
2) PLANS(I)		ALPHABETIC ARRAY IDENTIFYING EACH DATA CASE
3) uk	μ	Universal gravitational constant
4) AMASS	m_o	Initial mass of the vehicle
5) HMAX		Maximum integration step size
6) XOE(I)	$\binom{R}{V}$	Initial state vector
7) QOE(I)	$\binom{u}{\dot{u}}$	Estimated initial costate vector
8) LEGMAX		Number of burn and coast arcs
9) ITMAX		Maximum number of iterations allowed per case
10) ATP(I,1)	T_i	TIME AT START OF ARC I
11) ATP(LEGMAX + 1,1)	T_F	FINAL TIME
12) ATP(I,2)	Δm	MASS LOSS AT START OF ARC I. ONLY ALLOWED TO OCCUR AFTER BURN ARCS (I = 1,LEGMAX)
13) ATP(I,3)	$\dot{m}$	MASS RATE ALONG ARC I (I = 1, LEGMAX)
14) ATP(I,4)	T	THRUST ALONG ARC I. IF ZERO ARC ASSUMED TO BE COAST (I = 1,LEGMAX)
15) C(I)		Vector of constraints. Definition of elements of vector depend on boundary value problem under consideration. For the rendezvous problem the first six components of C contain the state of the target at some time which is contained in C(7). For the 5-constraint mission the first three components of C contain the desired angular momentum vector ($\overline{H} = \overline{R} \times \overline{V}$) and the next two elements contain the first two elements of the desired eccentricity vector ($\overline{E}$). ($\overline{E} = -[\frac{\overline{R}}{\lvert R \rvert} + \frac{\overline{H} \times \overline{V}}{\mu}]$)

2. Subroutine Out (Output Routine)

This routine controls the output operations for the total program. An integer flag variable, NPATH, controls which of three paths the program will follow.

If NPATH is negative, the SWITCH routine has just completed a burn arc and the OUT routine prints variables describing the immediately preceding coast (if one existed) and burn arcs. The coast arc is described by the state and costate at the end of the arc (X and Q), the integral of 1/RADIUS along the arc (PSY), twice the orbital energy (ALPHA) and the calculated coast time (FT). The burn arc is described by the state and costate at the end of the arc (XF and QF), the mass at the end of the arc (AM) and the number of integration steps used along the burn arc (ITBURN). Also outputted at this time are the orbital characteristics of the orbit defined by the state of the vehicle at the start of the burn arc. The semimajor axis (AAXIS), the minimum radius of the orbit (RMIN), the maximum radius (RMAX), the orbital energy (ENERGY), the period of the orbit (PERIOD), the angular velocity vector (H) and its magnitude (HMAG), the eccentricity vector (E1) and its magnitude (EMAG), and the radius (RMAG) are used to describe the orbit.

If NPATH is zero, a full iteration has been completed. The resultant orbit is described by its orbital characteristics. The total burn time, the lengths of the separate burn and coast arcs, the "miss" vector (DC), the determinant of the matrix E (partials of constraint functions with respect to the initial costate and switching times), the diagonal elements of E, the magnitude of the desired changes in control (DU) and control rate scaled by time (DUDT), the bound CK on adjustments to be made in QO and the switching times as well as the vector from whence CK was chosen, the requested changes in the initial costate and the switching times, and the switching times and initial costate to be used in the next iteration are printed.

If NPATH is positive, the program has completed the case and summary tables are printed. The tables include the total burn time, the lengths of the separate arcs, the "miss" vector (DC), DU, DUDT, CK, and initial

costate for each iteration performed.

This subprogram is called by SWITCH and calls no other programs.

3. Subroutine SWITCH

The SWITCH subroutine supervises the generation of trial trajectories and the Newton Raphson iterations. The program accepts as input the initial state (XOE), costate (QOE), the vehicle description, and estimated lengths of the burn and coast arcs. The routine performs the necessary initializations and calls the COAST routine to compute the results of coast arcs and the RKG031 routine to integrate the burn arcs. At the end of each arc, a new column of the matrix A of partials $\left(\frac{\partial x, q}{\partial q_o, t_1, \ldots, t_i}\right)$ is initialized corresponding to the time, t_i, at the end of the arc.

The partials are

$$\left(\frac{\partial x,q}{\partial t_i}\right)\Big|_{t_i}^{T} = \left(0,\ \pm\frac{v_{ex}|\dot{m}|}{m}\ \frac{u^T}{|u|},\ 0,\ 0\right)\Big|_{t_i}^{T}$$

where the sign is negative after coasts and positive after burns. After the last arc, always assumed to be a burn, the necessary column of partials is

$$\left(\frac{\partial x,q}{\partial t_F}\right)\Big|_{t_F} = (\dot{R},\ \ddot{R},\ \dot{u},\ u)^T$$

where t_F is final time.

The SWITCH routine also calculates the switching conditions and the necessary partials of these conditions with respect to initial costate and the switching times.

The switching condition across a burn arc from t_i to t_{i+1} is

$$T_V(t_{i+1}) - T_V(t_i) = 0$$

where

$$T_V = \dot{R}^T\dot{u} + \frac{\mu R^T u}{|R|^3}$$

The gradient of the variable, T_V, with respect to state and costate is

$$\frac{\partial T_V}{\partial x,q} = \left(\frac{\mu u^T}{|R|^3} - \frac{3\mu u^T R}{|R|^5}R^T,\ \dot{u}^T,\ \frac{\mu R^T}{|R|^3},\ \dot{R}^T\right)$$

and the partial of the burn switching condition, C_B, becomes

$$\frac{\partial C_B}{\partial q_o,t_1,\ldots,t_F} = \frac{\partial T_V}{\partial x,q}\Big|_{t_{i+1}}\frac{\partial x,q}{\partial q_o,t_1,\ldots t_{i+1}} - \frac{\partial T_V}{\partial x,q}\Big|_{t_i}\frac{\partial x,q}{\partial q_o,t_i t_i}$$

The switching condition across a coast from t_i to t_{i+1} is

$$|u|_{t_{i+1}} - |u|_{t_i} = 0$$

where

$$\frac{\partial |u|}{\partial x,q} = (0,\ 0,\ \frac{\bar{u}^T}{|u|},\ o)$$

and the partial of the coast switching condition C_c becomes

$$\frac{\partial C_c}{\partial q_o, t_1, \ldots, t_F} = \frac{\partial |u|}{\partial x,q}\bigg|_{t_{i+1}} \frac{\partial x,q}{\partial q_o, t_1, \ldots t_{i+1}} - \frac{\partial |u|}{\partial x,q}\bigg|_{t_i} \frac{\partial x,q}{\partial q_o, t_1, \ldots, t_i}$$

After the trajectory has been calculated SWITCH calls BVEVAL to evaluate the six terminal constraints and then calls ADJUST to calculate the Newton iterate desired. Another iteration is then performed with the new costate, QOl, and switching times (ATP(I,l)).

At the end of each iteration a test is made to see if the maximum number of iterations (KMAX) has been exceeded or if the new adjustments are less than the tolerances which indicates convergence. When either of these occur NO is set equal to zero and a final trajectory is computed propagating only the state and costate (not the partials).

The SWITCH program also calls OUT (the output routine) and controls the amount of printout.

4. Subroutine RKG031

This program propagates state, costate, and their transition matrix across a burn arc, using a numerical integration method especially adapted for the purpose. The inputs accepted as explicit arguments are the initial state and costate XO and QO and the initial matrix of partials Z, together with a desired error level indicator EVT, a step size limit HMAX, the number LEGMAX of the final leg, and the indicator NO which, if zero, suppresses computation of the partial derivatives. Other inputs accepted via COMMON are the number LEG of the current leg, and mass, thrust, and timing for that leg in the ATP array. Explicit outputs are state and costate XF and QF and the matrix of partials Z at the end of the arc. Also an integration step count ITBURN is an output through COMMON.

The program operates by repeatedly calling on RKSTEP to perform Runge-Kutta numerical integration steps. For the sake of efficiency, these steps are grouped into combination steps consisting of three short steps of integration of state and costate equations only and one overlapping triple length step of integration of state and costate equations and variational equations. Thus the computationally expensive right hand sides of the variational equations are called only 25% as often as the state and costate equations. This is permissible since the matrix of partials is relatively non-critical for accuracy, for it is used only in linearized Newton-Raphson adjustments which are only approximate anyway. Also the redundancy in integration of state and costate is useful in estimating integration accuracy so that step sizes can be continually reoptimized. The error estimate is obtained by the Richardson extrapolation technique, which (in this case) estimates the error in the result of the

three short steps to be one eightieth the difference between the result of the three short steps and the single long step. This error estimate is added in to eliminate the error to the extent that it was correctly estimated, and it is also used to determine the best step size for the next combination step. The desired error level for one step is assumed to be equal to the length of the step divided by the length of the entire burn arc, times a desired level for the total error over the burn arc. Estimated error is compared with desired error after each step, and step size for the next step is then altered by the fourth root of the ratio between the two. [Note: actual adjustments involve error squared so that an eighth root actually appears in the program.]

When the burn arc is the last of the trajectory, RKG031 also calls YDDRHS to obtain partials of state and costate with respect to final time TF and stores these partials as a final column of the Z matrix.

5. Subroutine RKSTEP

This subroutine performs a single fourth-order Runge-Kutta integration step on a system of second order differential equations for a matrix function Y consisting of 6 rows and at most 13 columns. The calling program supplies the following input values as explicit arguments:

YN = initial value of Y

YDN = initial value of the first derivative of Y

TN = initial time

H = step size

N = flag variable

LEG = number of columns in excess of 6 to be advanced as explicit arguments

and RKSTEP calculates the following values which are returned:

YN1 = value of Y at TN + H

YDN1 = value of the first derivative of Y at TN + H

If the flag variable, N, is positive, then the first 6 + LEG columns of Y are advanced. Otherwise, only the first column is advanced.

The method of attack consists of letting $\dot{Y} = F(Y,t)$ represent the differential equation of the matrix Y. Then, with

$$D_1 = H*F(YN,TN)$$

$$D_2 = H*F(YN + \frac{H}{2}(YDN + \frac{1}{4}D_1),\ TN + \frac{H}{2})$$

$$D_3 = H*F(YN + H*(YDN + \frac{1}{2}D_2),\ TN + H)$$

YN1 and YDN1 may be evaluated as

$$YN1 = YN + H*(YDN + \frac{1}{6}(D_1 + 2*D_2))$$

$$YDN1 = YDN = \frac{1}{6}(D_1 + 4*D_2 + D_3)$$

Evaluations of the form H*F(Y,t) which appears in the above equations are accomplished by calls to subroutine YDDRHS.

6. Subroutine YDDRHS

This subroutine performs an explicit evaluation of a matrix function YDD = H*F(Y,T) consisting of 6 rows and at most 13 columns. The calling program supplies values of the input variables Y,H and T and a flag variable N as explicit arguments. YDDRHS then calculates an appropriate value of YDD which is returned as an explicit argument. If the flag variable, N, is positive, then the first 6 + LEG columns of YDD are computed. If N is non-positive, then only the first column of YDD is calculated. The parameters UK, AM, LEG and ITBURN and the matrix ATP are transmitted via labeled common block /CCPINJ/.

The matrix YDD may be partitioned

$$YDD = \left[\begin{array}{c|c} RDD & \\ \hline UDD & WDD \end{array}\right]$$

and Y may be partitioned

$$Y = \left[\begin{array}{c|c} R & \\ \hline U & W \end{array}\right]$$

where RDD, UDD, R & U are 3 x 1 matrices (3-vectors) and WDD and W are 6 x (LEG + 5) matrices. Using standard vector-matrix notation, RDD, UDD, and WDD may be expressed in terms of R, U and W as

$$RDD = -\frac{\mu R}{|R|^3} - \frac{ATP(LEG,4)}{AM1} \frac{U}{|U|}$$

$$UDD = \frac{3\mu R^T U}{|R|^5} R - \frac{\mu U}{|R|^3}$$

$$WDD = BW$$

where μ = UK and the matrix B is given by

$$B = \left[\begin{array}{c|c} B_{11} & B_{12} \\ \hline B_{21} & B_{11} \end{array}\right]$$

The 3 x 3 sub-matrices of which B is composed are given in terms of R and U as

$$B_{11} = \frac{\mu}{|R|^3}\left(3\frac{RR^T}{|R|^2} - I_3\right)$$

$$B_{12} = \left(I_3 - \frac{UU^T}{|U|^2}\right) \frac{1}{|U|} \frac{ATP(LEG,4)}{AM1}$$

$$B_{21} = \left(I_3 - 5\frac{RR^T}{|R|^2}\right) \frac{3\mu R^T}{|R|^5} + (RU^T + UR^T) \frac{3\mu}{|R|^5}$$

7. Subroutine COAST

This program takes the initial state (RO,VO), initial costate (DRO,DVO), plus the desired coasting time and calculates the final state (R,V), final costate (DR,DV), and the matrix of partials of final state and costate with respect to initial state and costate. The state and costate vectors are transferred by labeled common ACOAST. The calling sequence contains as inputs the gravitational constant UK, a flag variable NO, ATP and LEG which are used to calculate the coasting time. IF NO equals zero only state and costate are propagated. IF NO is nonzero the partials are also calculated. The calling sequence also includes PHI and DPHI which are (6 x 6) matrices of partials. PHI is the partials of final state (costate) with respect to initial state (costate). DPHI is the partials of final costate with respect to initial state. The labeled common, WCOAST, transfers PSY (the integral of $|R|^{-1}$ over the coast), ALPHA (twice the orbital energy), and FT (the calculated coast time) to the output routine (OUT).

The general solutions for the two-body problem are presented in reference [2]. The equations presented in the paper by Goodyear are implemented as presented for the closed form calculation of R, V and PHI. It was noticed that the partials of final costate with respect to initial state (DPHI) was equal to the formal differential of the PHI matrix corresponding to letting costate be considered to be the differential of state (this fact is derived [1]). The variable names in-

---

[2] W. H. Goodyear. "Completely General Closed-Form Solution for Coordinates and Partial Derivatives of the Two-Body Problem," The Astronomical Journal, Vol. 70, No. 3, April, 1965, pp. 189-192.

ternal to COAST are a one-to-one mapping of the names used in the Goodyear paper. The differential of a variable is specified by a D in front of the variable name (.e.g. SO → DSO). It should be noted that final costate is evaluated as the differential of final state (DR,DV).

This program is called by subroutine SWITCH and calls a special purpose matrix multiply routine AMULT.

VARIABLE DEFINITIONS

	VARIABLE NAME COAST ROUTINE	VARIABLE DESCRIPTION
1)	RO	Initial radius
2)	VO	Initial velocity
3)	DRO	Initial control (u)
4)	DVO	Initial control rate ($\dot{u}$)
5)	R	FINAL RADIUS
6)	V	FINAL velocity
7)	DR	FINAL CONTROL
8)	DV	FINAL CONTROL RATE
9)	PHI	PARTIALS OF FINAL STATE/costate with respect to initial STATE/costate
10)	DPHI	PARTIALS OF FINAL COSTATE with respect to initial state
11)	PSY	ψ as defined in reference [2] (Goodyear)
12)	ALPHA	Twice orbital energy
13)	FT	Calculated coast time

8. <u>Subroutine BVEVAL</u>

This program is used for evaluation of the six right end and (PERHAPS) transversality conditions which are needed to specify the desired final orbit. The program computes the difference DC between the desired value of the terminal constraints and their actual values as determined from XF and QF. It also computes the matrix E of partial derivatives of the right end conditions with respect to QO and the switching times. Two versions of subprogram BVEVAL are presented here: one for a five-constraint orbital injection with time origin free, and the other for rendezvous which involves a full complement of six constraints on final state.

The five-constraint version of the program assumes the six terminal conditions consist of the angular velocity vector, the first two components of the eccentricity vector, and one transversality variable at T_F. The program calculates the partial derivatives of these constraints with respect to XF and QF and multiplies them by the matrix Z (partial derivatives of XF and QF with respect to QO and the switching times) to form the matrix E of partial derivatives of the terminal constraints with respect to QO and the switching times.

The rendezvous version of the program uses as constrained terminal variables the full state vector at final time. In this case the C vector which specifies the terminal manifold contains the state of the target vehicle in its first six components and the corresponding time in its seventh component. In order to form the DC vector, the state of the target vehicle is propagated to T_F and subtracted from the actual XF. The matrix of partials of right end conditions with respect to QO and

the switching times becomes for this case the first six rows of the Z matrix except that the partial derivative of target state with respect to T_F is subtracted from the last column of E to produce the matrix of partial derivatives of the DC vector with respect to QO and the switching times. The rendezvous version of BVEVAL prints the state of the target vehicle at T_F following each iteration and prints the orbital characteristics of the target orbit after the first iteration.

The BVEVAL subroutine is called from SWITCH and calls no other routines.

9. Subroutine ADJUST

This subprogram adjusts the initial costate vector (QO) and the switching times (ATP(I,1)) based on linearized relations between these quantities and a vector C of constraint functions which is desired to change by an amount DC (the "miss" vector). The inputs are QO, ATP, E (the matrix of partials of C with respect to QO and the switching times), Z (the matrix of partials of state and costate with respect to QO and switching times) and LEGMAX. The vector DC appears as an additional column of the E matrix.

The explicit outputs from the routine are new initial costate (QO) and new switching times (ATP(I,1)), the magnitude of the desired change in the initial control vector (DU) and the magnitude of the desired change in the initial control rate vector times total mission time (DUDT). The bound CK on adjustments allowed on QO and the switch-

ing times and the vector A containing the maximum allowable changes in the switching times and QO are passed directly to OUT via labeled common WADJ. The matrix E may also be considered an output since it is altered during the execution of this program.

The desired change in the QO vector and the switching times (t_i; $i = 1$, LEGMAX) is obtained by solving the following simultaneous equations:

$$\Delta c = \left[\frac{\partial c}{\partial QO, t_1, \ldots, t_F} \right] \begin{bmatrix} \Delta QO \\ \Delta t_1 \\ \cdot \\ \cdot \\ \cdot \\ \Delta t_F \end{bmatrix}$$

by calling subroutine SOLVE. The desired change in the QO and the t_i's is placed in the LEGMAX + 7 column of the E matrix.

In order to insure convergence only a fraction, CK, of the desired linearized changes in initial costate and switching times is accepted. CK is determined as the largest number (S1) compatible with the following restrictions: the magnitude of the change in the initial control vector (DU) is limited to .2, the magnitude of the change in the initial control rate (DUD) is limited to .0003 and the length of the burn and coast arcs is allowed to change by at most 50%. [This prevents arc durations from disappearing or becoming negative.] However, no restriction is placed on the allowable change in the duration of initial coasts. This allows for the possibility of negative initial coast durations, i.e. the first burn may begin before the (arbitrary) epoch t_o if it is optimal for it to do so.

The new QO and switching times are then defined by adding to their previous values increments equal to CK times the Newton Raphson increments. The new QO vector is then normalized such that its first three components (u) have a magnitude of unity.

This subprogram is called by SWITCH and calls SOLVE.

10. Subroutine SOLVE

This program solves a system

$$\sum_{j=1}^{6+\mathrm{LEGMAX}} A_{ij} X_j = A_{iL}, i = 1,\ldots 6 + \mathrm{LEGMAX};\ L = 7 + \mathrm{LEGMAX}$$

of linear simultaneous equations for the unknowns (X_j). The inputs are the elements of the matrix A, with last column (A(I,7 + LEGMAX)) containing the right hand sides of the equations and LEGMAX specifying the number of equations to be solved. The output is the same matrix A with the last column replaced by the solution vector $\overline{X}$ and the other columns destroyed (by the Gauss-Jordan reduction transformations used to solve the linear system).

The solution is obtained directly by Gauss-Jordan reduction without generating the inverse of the coefficient matrix as an intermediate result. In order to avoid undue round off errors, at the ith stage of the reduction process the unreduced rows are sorted such that element i + 1 of row i + 1 is at least as large in magnitude as the corresponding element of any later row. This has no effect on the ordering of the solution vector.

This program is called from ADJUST and calls no other routines.

APPENDIX I

SWITCH Program Listing

```
C  ********     MAIN ROUTINE      **********
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/CCPINJ/UK,ATP(7,4),AM,LEG,ITBURN
      COMMON/WIN/PLANS(54),NOUT,LOGIC
       DIMENSION C(12),Q0E(6),X0E(6)
 1     FORMAT(7F10.1)
C READ INTEGER VARIABLE NCASE , RIGHT ADJUSTED IN COLUMNS 1-2 , WHICH
C IS THE NUMBER OF DATA CASES FOLLOWING
      NIN=2
      NOUT=8
      READ(NIN,3) NCASE
       NC=0
 5     NC=NC+1
      LOGIC=0
      WRITE(NOUT,6) NC
 6     FORMAT(1H1,13H CASE NUMBER ,I2,//)
      READ(NIN,10) PLANS
 10   FORMAT(18A4)
      WRITE(NOUT,10) PLANS
C FIRST THREE CARDS OF EACH CASE CONTAIN ALPHABETIC INFORMATION IN
C COLUMNS 1-72 DESCRIPING THE CASE BEING SOLVED
       READ(NIN,1)UK,AMASS,HMAX
C THE NEXT CARD CONTAINS THE GRAVIATIONAL CONSTANT , UK ,(COLS 1-10),
C THE INITIAL MASS OF THE VEHICLE , AMASS ,(COLS 11-20) AND THE MAXIMUM
C ALLOWABLE INTEGRATION STEP SIZE , HMAX ,(COLS 21-30) ALL UNDER
C FORMAT F10.1
       READ(NIN,1)X0E
C THE NEXT CARD CONTAINS THE SIX VECTOR X0E WHICH IS THE INITIAL STATE
C OF THE VEHICLE UNDER A 6F10.1 FORMAT.
       READ(NIN,1)Q0E
C NEXT IS THE INITIAL COSTATE VECTOR , CONTROL AND CONTROL RATE(Q0E) ,
C UNDER 6F10.1 FORMAT.
       READ(NIN,1) (C(I),I=1,7)
C THE 7-VECTOR , C , IS READ NEXT UNDER A 7F10.1 FORMAT. THE VECTOR
C CONTAINS THE DESIRED VALUES OF THE RIGHT END CONSTRAINTS OF THE
C MISSON. THE BOUNDARY CONDITIONS FOR A RENDEZVOUS MISSON ARE THE STATE
C (LOCATED IN FIRST SIX COMPONENTS OF C) AND CORRESPONDING TIME(IN C(7))
C DEFINING THE ORBITAL POSITION OF THE TARGET VEHICLE. FOR THE
C 5-CONSTRAINT MISSON THE FIRST THREE COMPONENTS OF C CONTAIN THE
C DESIRED ANGULAR MOMENTUM VECTOR(H= R X V) AND THE NEXT TWO ELEMENTS
C OF C CONTAIN THE FIRST TWO ELEMENTS OF THE ECCENTRICITY VECTOR (E).
      READ(NIN,3) LEGMAX,IMAX
C THE NUMBER OF BURN AND COAST ARCS , LEGMAX , AND THE MAXIMUM NUMBER OF
C ITERATIONS ALLOWABLE , IMAX ,APPEAR ON THE NEXT CARD WITH A 2I2 FORMAT
 3     FORMAT(2I2)
 4     FORMAT(4F10.1)
       L1=LEGMAX+1
       READ(NIN,4)  (ATP(I,1),ATP(I,2),ATP(I,3),ATP(I,4),I=1,L1)
C ATP MATRIX CONTAINS A ROW DESCRIPING VEHICLE CHARACTERISTICS FOR EACH
C SEPERATE ARC. ATP(I,1) - TIME AT START OF ARC I , ATP(I,2) - MASS LOSS
C AT START OF ARC I (ONLY AFTER BURN ARCS) , ATP(I,3) - MASS RATE ON ARC
C I , ATP(I,4) - THRUST ALONG ARC I (IF ZERO ASSUMED COAST). ATP ARRAY
C ALSO HAS A ROW CONTAINING FINAL TIME(TF=ATP(LEGMAX+1,1)). THE MATRIX
C IS INPUTTED ONE ROW PER CARD UNDER A 4F10.1 FORMAT.
      WRITE(NOUT,100)UK,AMASS,HMAX,IMAX,LEGMAX
```

```
 100  FORMAT('0GRAVITATIONAL CONSTANT='F10.2,' INITIAL MASS='E16.8,' MAX
     1 INTEGRATION STEP='F10.3,/' MAX NUMBER OF ITERATIONS='I3,' NUMBER
     2OF SEPERATE ARCS=',I3,/)
      WRITE(NOUT,101) (ATP(I,1),ATP(I,2),ATP(I,3),ATP(I,4),I=1,L1)
 101  FORMAT('0'35X'ATP ARRAY'//,8X'TIME'13X'DELTA MASS'10X'MASS RATE'
     113X'THRUST'//(1X,4E20.8))
      WRITE(NOUT,102)X0E,Q0E,(C(I),I=1,7)
 102  FORMAT(17H0INITIAL STATE X0,6F17.7/16H    ESTIMATED Q0,6F17.7/
     116H0DESIRED FINAL C,7E16.8/)
       CALL SWITCH(AMASS,LEGMAX,IMAX,C,Q0E,X0E,HMAX)
       IF(NCASE.GT.NC) GO TO 5
       STOP
       END


      SUBROUTINE OUT(X,Q,XF,QF,LEGMAX,NPATH)
      IMPLICIT REAL*8(A-H,O-Z)
C ROUTINE FOR PRINTING DATA. X , Q -STATE AND COSTATE AT BEGINNING OF
C ARC JUST COMPLETED. XF , QF - STATE AND COSTATE AT END OF ARC. NPATH -
C INTEGER VARIABLE CONTROLLING PRINT OPTIONS( IF NEGATIVE - END OF LEG ,
C IF ZERO - END OF ITERATION , IF POSTIVE - END OF CASE ).
      COMMON/CCPINJ/UK,ATP(7,4),AM,LEG,ITBURN
      COMMON/WIN/PLANS(54),NOUT,LOGIC
       COMMON/WADJ/A(8),CK
       COMMON/WCOAST/PSY,ALPHA,FT
       COMMON/WSWIT/B(12,13),DC(12),DU,DUDT,EVT,BURNT,KCOUNT
       DIMENSION X(6),H(3),E1(3),TIME(50,7),DC1(50,12),DU1(50),DUD1(50)
       DIMENSION KC1(50),Q(6),XF(6),QF(6),CK1(50),CQ0(50,6)
       IF(NPATH) 1,2,2
 1     LEG1=LEG-1
       IF(LEG.LT.3) WRITE(NOUT,40) KCOUNT
 40    FORMAT(1H0,17HITERATION NUMBER ,I3,/)
       IF(LEG.EQ.1) GO TO 2
       WRITE(NOUT,10)LEG1,X,Q
C OUTPUT STATE AND COSTATE AT END OF COAST
 10    FORMAT(20X,9HCOAST ARC,/25X,4HLEG=,
     1I2,1X12HSTATE AT END,1X,6E14.6,/30X,14HCOSTATE AT END,1X,6E14.6)
       WRITE(NOUT,22)PSY,ALPHA,FT
C COAST ARC PARAMETERS - PSY = INTEGRAL OF 1/R OVER COAST , ALPHA =
C TWICE THE ORBITAL ENERGY , FT = CALCULATED COAST TIME
 22     FORMAT(30X,4HPSY=,E14.6,5X,6HALPHA=,E14.6,5X,22HCALCULATED COAST T
     1IME=,E14.6)
 2      H(1)=X(2)*X(6)-X(3)*X(5)
C CALCULATION OF THE ORBIIAL ELEMENTS FOR THE ORBIT DEFINED BY X
        H(2)=X(3)*X(4)-X(1)*X(6)
        H(3)=X(1)*X(5)-X(2)*X(4)
        HM=DSQRT(H(1)**2+H(2)**2+H(3)**2)
        RM=DSQRT(X(1)**2+X(2)**2+X(3)**2)
        E1(1)=-(X(1)/RM+(H(2)*X(6)-H(3)*X(5))/UK)
        E1(2)=-(X(2)/RM+(H(3)*X(4)-H(1)*X(6))/UK)
        E1(3)=-(X(3)/RM+(H(1)*X(5)-H(2)*X(4))/UK)
        EM=DSQRT(E1(1)**2+E1(2)**2+E1(3)**2)
        ENERGY=-UK/RM+.5*(X(4)**2+X(5)**2+X(6)**2)
        AAXIS=-UK/(2.0*ENERGY)
```

```
        RMIN=AAXIS*(1.0-EM)
        RMAX=AAXIS*(1.0+EM)
        PERIOD=(6.2831853)*DSQRT(DABS(AAXIS**3/UK))
      IF(NPATH.GE.0) WRITE(NOUT,41)
 41   FORMAT(22X,30HRESULTANT ORBIT SPECIFICATIONS)
        WRITE(NOUT,11)AAXIS,RMIN,RMAX,ENERGY,PERIOD,HM,H,EM,E1,RM
 11   FORMAT(25X,15HSEMIMAJOR AXIS=,E14.6,1X5HRMIN=,E14.6,1X5HRMAX=,E14
     1.6,1X7HENERGY=,E14.6,/25X,7HPERIOD=,E14.6,1X5HHMAG=,E14.6,1X8HH VE
     2CTOR,3E14.6,/25X5HEMAG=,E14.6,1X8HE VECTOR,3E14.6,1X5HRMAG=,E14.6)
      IF(NPATH)5,6,6
 5      WRITE(NOUT,12)LEG,XF,QF,AM,ITBURN
C OUTPUT STATE , COSTATE AND MASS AT END OF BURN
 12     FORMAT(20X,8HBURN ARC,/25X,4HLEG=,I2,1X12HSTATE AT END,1X6E14.6,/
     130X,14HCOSTATE AT END,1X6E14.6,/30X,19HMASS AT END OF LEG=,E14.6,
     25X,'NUMBER OF INTEGRATION STEPS IN BURN ARC='I4)
        IF(LEG.LT.LEGMAX) RETURN
        KC=MOD(KCOUNT-1,50)
        KC=KC+1
        DO 7 I=1,LEG
 7      TIME(KC,I)=ATP(I+1,1)-ATP(I,1)
        RETURN
 6      L6=6+LEG
      TIME(KC,7)=BURNT
        WRITE(NOUT,13)TIME(KC,7),(TIME(KC,I),I=1,LEG)
C OUTPUT TOTAL BURN TIME AND LENGTH OF ARCS
 13   FORMAT(20X,16HTOTAL BURN TIME=,E14.6,1X9HARC TIMES,1X4E14.6,/61X
     12E14.6)
      IF(NPATH.GT.0) GO TO 3
      DETE=1.0
      DO 4 I=1,L6
 4    DETE=DETE*E(I,I)
        WRITE(NOUT,14)DC,DETE,(E(I,I),I=1,L6)
C PRINT VECTOR OF ERRORS IN BOUNDARY CONDITIONS(DC) AND DETERMINANT AND
C DIAGONAL ELEMENTS OF MATRIX OF PARTIALS OF BOUNDARY CONDITIONS WITH
C RESPECT TO INITIAL COSTATE AND SWITCHING TIMES
 14   FORMAT(25X,2HDC,1X6E14.6,/28X,6E14.6,/25X,17HDETERMINANT OF E=,
     1E14.6,1X13HDIAGONAL OF E,4E14.6,/25X,8E14.6)
        L1=LEG+1
        L2=L1+1
        WRITE(NOUT,15)DU,DUDT,CK,EVT,(A(I),I=1,L2)
 15   FORMAT(25X,3HDU=,E14.6,6H DUDT=,E14.6,4H CK=,E14.6,5H EVT=,E14.6/
     125X,10HCK=MIN OF ,7E13.5)
        L7=LEG+7
        WRITE(NOUT,30)(E(I,L7),I=1,L6)
 30   FORMAT(/25X66HCHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES
     1AND FINAL TIME,/25X,6E14.6,/35X,6E14.6)
       WRITE(NOUT,16)KCOUNT,QF,(ATP(I,1),I=2,L1)
 16   FORMAT(1X,24HEND OF ITERATION NUMBER ,I3,/15X,7HNEW Q0 ,6E14.6,/
     115X,16HNEW SWITCH TIMES,1X6E14.6,//)
        DO 8 I=1,6
        CQ0(KC,I)=QF(I)
        DC1(KC,I)=DC(I)
 8      DC1(KC,I+6)=DC(I+6)
        CK1(KC)=CK
        DU1(KC)=DU
```

```
      DUD1(KC)=DUDT
      KC1(KC)=KCOUNT
      RETURN
 3    KCP=KCOUNT
      IF(KCP.GT.50) KCP=50
      KC1(KC)=KCOUNT
      WRITE(NOUT,115) PLANS
 115  FORMAT(1H1,(18A4))
      WRITE(NOUT,17)
 17   FORMAT(1H0,50X,14HSUMMARY TABLES,//,1X9HITERATION,1X15HTOTAL BURN
     1 TIME,21X,29HLENGTH OF BURN AND COAST ARCS,/2X6HNUMBER,//)
      DO 9 I=1,KCP
 9    WRITE(NOUT,18) KC1(I),TIME(I,7),(TIME(I,J),J=1,LEG)
 18   FORMAT(3X,I3,5X,7E15.7)
      WRITE(NOUT,19)
 19   FORMAT(1H0,//1X9HITERATION,39X,36HERROR IN BOUNDARY CONDITIONS-DC(
     11-8),/2X,6HNUMBER,//)
      KC1(KC)=KC1(KC-1) + 1
      IF(KCOUNT.LE.50) KCP=KCP-1
      WRITE(NOUT,20)(KC1(I),(DC1(I,J),J=1,8),I=1,KCP)
 20   FORMAT(3XI3,5X,8E14.6)
      WRITE(NOUT,21)
 21   FORMAT(1H0,//1X9HITERATION,26X,8HDC(9-12),33X,2HDU,12X,4HDUDT,12X2
     1HCK,/2X6HNUMBER,//)
      WRITE(NOUT,18)(KC1(I),(DC1(I,J),J=9,12),DU1(I),DUD1(I),CK1(I),I=1
     1,KCP)
      WRITE(NOUT,51)
 51   FORMAT(1H0,//1X9HITERATION,30X,37HNEW Q0 GENERATED BY PRESENT ITER
     1ATION,/2X6HNUMBER,//)
      J=0
      WRITE(NOUT,52) J,Q
 52   FORMAT(3XI3,5X,6E16.8)
      WRITE(NOUT,52) (KC1(I),(CQ0(I,J),J=1,6),I=1,KCP)
      RETURN
      END


      SUBROUTINE SWITCH(AMASS,LEGMAX,IMAX,C,Q0E,X0E,HMAX)
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/CCPINJ/UK,ATP(7,4),AM,LEG,ITBURN
      COMMON/FSWIT/E(12,13),DC(12),DU,DUDT,EVT,BURNT,KCOUNT
      COMMON/ACOAST/X0(6),Q0(6),XF(6),QF(6)
      DIMENSION C(12),Z(12,12),X0E(6),Q01(6)
      DIMENSION Q0E(6),DUMMY(13),PHI(6,6),DPHI(6,6),DZ(12,12)
      KCOUNT=0
      NO=1
      L7=7+LEGMAX
      L6=6+LEGMAX
      EVT=1.E-8
      KMAX=IMAX
      L1=LEGMAX+1
      DO 2 I=1,6
 2    Q01(I)=Q0E(I)
********************************
```

```
C  START OF EACH ITERATION
C ********************************
 1      LEG=1
       MTEST=0
        AM=AMASS
        KCOUNT=KCOUNT+1
        BURNT=0.0
C INITIALIZATION OF STATE(X0) AND COSTATE(Q0)
        DO 3 I=1,6
        Q0(I)=Q01(I)
 3      X0(I)=X0E(I)
C INITIALIZATION OF MATRIX OF PARTIALS
C Z(I,J) PARTIAL OF STATE AND COSTATE WITH RESPECT TO INITIAL COSTATE
C AND SWITCHING TIMES
C E(I,J) PARTIAL OF RIGHT END VARIABLES AND SWITCHING CONDITIONS WITH
C RESPECT TO INITIAL COSTATE AND SWITCHING TIMES
        DO 4 I=1,12
        E(I,13)=0.0
        DO 4 J=1,12
        E(I,J)=0.0
 4      Z(I,J)=0.0
        DO 5 I=1,6
 5      Z(I+6,I)=1.0
       LEG5=6
       LEG6=7
        IF(ATP(1,4))6,7,6
C CALLED TO PROPAGATE COAST ARCS
C PHI(I,J) - PARTIAL OF STATE AT END OF COAST WITH RESPECT TO STATE
C AT START OF COAST
C DPHI(I,J) - PARTIAL OF COSTATE AT END OF COAST WITH RESPECT TO STATE
C AT START OF COAST
 7      CALL COAST(PHI,DPHI,UK,LEG,ATP,NO)
        DO 30 I=1,6
       I6=I+6
        DO 30 J=1,LEG5
        DZ(I,J)=0.0
        DZ(I6,J)=0.0
        DO 30 K=1,6
       DZ(I,J)=DZ(I,J)+PHI(I,K)*Z(K,J)
 30    DZ(I6,J)=DZ(I6,J)+PHI(I,K)*Z(K+6,J)+DPHI(I,K)*Z(K,J)
C UPDATE MATRIX OF PARTIALS Z
        DO 31 I=1,12
        DO 31 J=1,LEG5
 31     Z(I,J)=DZ(I,J)
        UM=DSQRT(QF(1)**2+QF(2)**2+QF(3)**2)
       CBMU=ATP(LEG+1,4)/(AM*UM)
C ADDITION OF NEW COLUMN TO Z CORRESPONDING TO TIME AT END OF COAST
        DO 8 I=1,3
  8     Z(I+3,LEG6)=-CBMU*QF(I)
        IF(LEG.LE.1) GO TO 173
C CALCULATION OF SWITCHING CONDITION AND CORRESPONDING PARTIAL
        E(LEG5,L7)=UMP-UM
        DO 9 J=1,LEG5
        E(LEG5,J)=-E(LEG5,J)
        DO 9 K=1,3
```

```
 9     E(LEG5,J)=E(LEG5,J)+(QF(K)/UM)*Z(K+6,J)
  173   LEG=LEG+1
       LEG5=LEG+5
       LEG6=LEG+6
       MTEST=1
        GO TO 12
C CALLED TO PROPAGATE BURN ARCS
C X0(Q0) - STATE(COSTATE) AT START OF BURN
C XF(QF) - STATE(COSTATE) AT END OF BURN
 6     CALL RKG031(X0,Q0,XF,QF,Z,EVT,HMAX,LEGMAX,NO)
        BURNT=BURNT+ATP(LEG+1,1)-ATP(LEG,1)
        CALL OUT(X0,Q0,XF,QF,LEGMAX,-1)
       IF(LEG.GE.LEGMAX) GO TO 12
        UM=DSQRT(QF(1)*QF(1)+QF(2)*QF(2)+QF(3)*QF(3))
        UMP=UM
       CBMU=ATP(LEG,4)/(AM*UM)
C ADDITION OF NEW COLUMN OF Z CORRESPONDING TO TIME AT END OF BURN
        DO 14 I=1,3
  14    Z(I+3,LEG6)=CBMU*QF(I)
C CALCULATION OF PARTIAL OF CONTROL(U) MAGNITUDE WITH RESPECT TO
C INITIAL COSTATE AND SWITCHING TIMES
        DO 15 J=1,LEG6
        DO 15 K=1,3
  15    E(LEG6,J)=E(LEG6,J)+(QF(K)/UM)*Z(K+6,J)
        IF(LEG.LE.1) GO TO 170
C CALCULATION OF TRANSVERSALITY CONDITION AND CORRESPONDING PARTIAL
C WITH RESPECT TO INITIAL COSTATE AND SWITCHING TIMES
  12    R2=XF(1)*XF(1)+XF(2)*XF(2)+XF(3)*XF(3)
        RS=XF(1)*QF(1)+XF(2)*QF(2)+XF(3)*QF(3)
        C3=-UK/(R2*DSQRT(R2))
        C4=-3.0*C3*RS/R2
       E(LEG5,L7)=XF(4)*QF(4)+XF(5)*QF(5)+XF(6)*QF(6)-C3*RS
      1 -E(LEG5,L7)
        DO 16 I=1,3
        DUMMY(I)=-C3*QF(I)-C4*XF(I)
        DUMMY(I+3)=QF(I+3)
        DUMMY(I+6)=-C3*XF(I)
  16    DUMMY(I+9)=XF(I+3)
        DO 17 J=1,LEG6
        DO 17 K=1,12
 17    E(LEG5,J)=-DUMMY(K)*Z(K,J)+E(LEG5,J)
       IF(MTEST.LE.0) GO TO170
       MTEST=0
       DO 172 J=1,LEG6
 172     E(LEG5,J)=-E(LEG5,J)
        E(LEG5,LEG5)=0.
       LEG=LEG-1
 170    IF(LEG.GE.LEGMAX) GO TO 18
           DO 19 I=1,6
        Q0(I)=QF(I)
  19     X0(I)=XF(I)
        LEG=LEG+1
       LEG5=LEG+5
       LEG6=LEG+6
        IF(ATP(LEG,4).EQ.0) GO TO 7
```

```
      GO TO 6
C CALLED TO CALCULATE RIGHT END VARIABLES
C XF - FINAL STATE  ,  QF - FINAL COSTATE
  18   CALL BVEVAL(XF,QF,Z,C,E,DC)
       DO 20 I=1,6
       I6=I+6
       E(I,L7)=DC(I)
       DC(I6)=E(I6,L7)
 20    E(LEG6,I)=Q01(I)
      IF(NO.EQ.0) GO TO 79
C CALLED TO SOLVE SIMULTANEOUS EQUATIONS AND DETERMINE NEW INITIAL
C COSTATE AND SWITCHING TIMES . Q01 - INITIAL COSTATE
       CALL ADJUST(Q01,E,Z,DU,DUDT,LEGMAX,ATP)
       CALL OUT(XF,QF,X0,Q01,LEGMAX,0)
       IF(KCOUNT.GE.KMAX) GO TO 78
      IF(DU.GT..0001.AND.DUDT.GT..001) GO TO 1
C ALLOWS PROPAGATION OF NEW TRAJECTORY WITHOUT CALCULATION OF PARTIALS
  78  NO=0
      GO TO 1
 79    CALL OUT(XF,Q0E,X0,QF,LEGMAX,1)
       RETURN
      END


      SUBROUTINE RKG031(X0,Q0,XF,QF,Z,EVT,HMAX,LEGMAX,NO)
      IMPLICIT REAL*8 (A-H,O-Z)
C THIS ROUTINE GOVERNS THE PROPAGATION OF BURN ARCS BY CALLING THE
C NUMERICAL INTEGRATION ROUTINES. IT DETERMINES THE INTEGRATION STEP
C SIZE(H) BY AN ESTIMATING ERROR AFTER EACH INTEGRATION STEP.
C X0 AND Q0 ARE STATE AND COSTATE AT START OF ARC. XF AND QF ARE STATE
C AND COSTATE AT END OF ARC. Z IS MATRIX OF PARTIALS.
      COMMON/CCPINJ/UK,ATP(7,4),AJ,LEG,ITBURN
      DIMENSION X0(6),Q0(6),XF(6),QF(6),Z(12,12),YN(6,13),YDN(6,13),
     1Y3H(6,13),YD3H(6,13),YM(6,13),YDM(6,13),EY(6),EYD(6)
      ITBURN=0
       LEG6=LEG+6
      DO 1 I=1,3
       YN(I,1)=X0(I)
       YN(I+3,1)=Q0(I)
       YDN(I,1)=X0(I+3)
      YDN(I+3,1)=Q0(I+3)
      DO 1 J=2,LEG6
      J1=J-1
       YN(I,J)=Z(I,J1)
       YN(I+3,J)=Z(I+6,J1)
       YDN(I,J)=Z(I+3,J1)
       YDN(I+3,J)=Z(I+9,J1)
       TF=ATP(LEG+1,1)
       T0=ATP(LEG,1)
      H=DSIGN(HMAX,TF-T0)
      TN=T0
      GO TO 7
    2 HO3=H/3.
      ITBURN=ITBURN+1
```

```
C CALL RKSTEP TO PERFORM NUMERICAL INTEGRATION
       CALL RKSTEP(YN,YDN,TN,Y3H,YD3H,H,NO,LEG)
       CALL RKSTEP(YN,YDN,TN,YM,YDM,HO3,0,LEG)
       CALL RKSTEP(YM,YDM,TN+HO3,YM,YDM,HO3,0,LEG)
       CALL RKSTEP(YM,YDM,TN+HO3*2.,YM,YDM,HO3,0,LEG)
      DO 3 I=1,6
      EY(I)=.125E-1*(YM(I,1)-Y3H(I,1))
    3 EYD(I)=.125E-1*(YDM(I,1)-YD3H(I,1))
      EV2MIN=1.E-13*(YDM(1,1)*YDM(1,1)+YDM(2,1)*YDM(2,1)+
     1YDM(3,1)*YDM(3,1))
       EVL2=DMAX1(EVT*(H/(TF-T0))**2,EV2MIN)
       R=(EYD(1)*EYD(1)+EYD(2)*EYD(2)+EYD(3)*EYD(3))/EVL2
C UPDATE STATE , COSTATE AND PARTIALS
       DO 5 I=1,6
      YN(I,1)=YM(I,1)+EY(I)
    5 YDN(I,1)=YDM(I,1)+EYD(I)
      DO 6 I=1,6
       DO 6 J=2,LEG6
      YN(I,J)=Y3H(I,J)
    6 YDN(I,J)=YD3H(I,J)
      IF( DABS(H) .GE. DABS(TF-TN) ) GO TO 8
      TN=TN+H
      IF(R.LT. 0.04) R=.04
      H=H/R**.125
C DETERMINE STEP SIZE(H) FOR NEXT INTEGRATION STEP
    7 IF ( DABS(H) .GT. DABS(TF-TN)  ) H=TF-TN
      IF( DABS(H) .GT. HMAX) H=DSIGN(HMAX,H)
      GO TO 2
 8     IF(LEG.LT.LEGMAX) GO TO 10
C CALCULATION OF PARTIAL OF XF AND QF WITH RESPECT TO FINAL TIME (TF)
      ONE=1.D0
      CALL YDDRHS(YN,YD3H,ONE,ATP(LEG+1,1),0)
      L6=6+LEGMAX
       DO 11 I=1,3
       Z(I,L6)=YDN(I,1)
       Z(I+3,L6)=YD3H(I,1)
       Z(I+6,L6)=YDN(I+3,1)
 11    Z(I+9,L6)=YD3H(I+3,1)
 10    DO 12 I=1,3
       XF(I)=YN(I,1)
       XF(I+3)=YDN(I,1)
       QF(I)=YN(I+3,1)
       QF(I+3)=YDN(I+3,1)
       DO 12 J=2,LEG6
      J1=J-1
       Z(I,J1)=YN(I,J)
       Z(I+3,J1)=YDN(I,J)
       Z(I+6,J1)=YN(I+3,J)
 12    Z(I+9,J1)=YDN(I+3,J)
       AM=AM-ATP(LEG,3)*(ATP(LEG+1,1)-ATP(LEG,1))-ATP(LEG+1,2)
      RETURN
      END
```

```
      SUBROUTINE RKSTEP(YN,YDN,TN,YN1,YDN1,H,N,LEG)
      IMPLICIT REAL*8(A-H,C-Z)
C  THIS PROGRAM ADVANCES YN AND YDN BY A STEP OF SIZE H TO YN1 AND YDN1
C  USING A FOURTH-ORDER RUNGE-KUTTA NUMERICAL INTEGRATION SCHEME. IF N
C  IS POSITIVE, ALL ELEMENTS OF THE MATRICES YN AND YDN ARE ADVANCED.
C  OTHERWISE ONLY THE FIRST COLUMN OF EACH MATRIX IS UPDATED.
      DIMENSION YN(6,13),YDN(6,13),D1(6,13),D2(6,13),D3(6,13),Y(6,13)
     1,YN1(6,13),YDN1(6,13)
      JMAX=1
       IF(N.GT.0) JMAX=6+LEG
      H2=.5*H
      CALL YDDRHS(YN,D1,H,TN,N)
      DO 1 J=1,JMAX
      DO 1 I=1,6
    1 Y(I,J)=YN(I,J)+H2*(YDN(I,J)+.25*D1(I,J))
      CALL YDDRHS(Y,D2,H,TN+H2,N)
      DO 2 J=1,JMAX
      DO 2 I=1,6
    2 Y(I,J)=YN(I,J)+H*(YDN(I,J)+.5*D2(I,J))
      CALL YDDRHS(Y,D3,H,TN+H,N)
      DO 3 J=1,JMAX
      DO 3 I=1,6
      YN1(I,J)=YN(I,J)+H*(YDN(I,J)+(D1(I,J)+2.*D2(I,J))/6.)
    3 YDN1(I,J)=YDN(I,J)+(D1(I,J)+4.*D2(I,J)+D3(I,J))/6.
      RETURN
      END


      SUBROUTINE YDDRHS(Y,YDD,H,T,N)
      IMPLICIT REAL*8(A-H,C-Z)
C THIS PROGRAM CALCULATES THE RIGHT HAND SIDES OF THE DIFFERENTIAL EQUA-
C TIONS DEFINING THE SECOND TIME DERIVATIVES OF R, U AND W. YDD IS A
C MATRIX CONSISTING OF RDD, UDD AND WDD. Y CONSISTS OF R, U AND W. H IS
C THE STEP SIZE OF PRESENT STEP, T IS PRESENT TIME AND N IS AN INDICATOR
C DETERMINING WHETHER WDD IS TO BE CALCULATED AT THIS EXECUTION .
      COMMON/CCPINJ/UK,ATP(7,4),AM,LEG,ITBURN
      DIMENSION Y(6,13),YDD(6,13),R(3),U(3),B(6,6)
C  COMPUTE BASIC QUANTITIES COMMON TO MANY COMPONENTS OF YDD.
       LEG6=6+LEG
      DO 1 I=1,3
      R(I)=Y(I,1)
    1 U(I)=Y(I+3,1)
      AM1=AM-(T-ATP(LEG,1))*ATP(LEG,3)
      R2=1./(R(1)*R(1)+R(2)*R(2)+R(3)*R(3))
      U2=1./(U(1)*U(1)+U(2)*U(2)+U(3)*U(3))
      UM=DSQRT(U2)
      RU=R(1)*U(1)+R(2)*U(2)+R(3)*U(3)
      ALPHA=-H*UK*R2*DSQRT(R2)
       BETA=H*UM*ATP(LEG,4)/AM1
      GAMMA=-3.*ALPHA*R2*RU
      DO 2 I=1,3
C  COMPUTE RDD AND UDD.
      YDD(I,1)=R(I)*ALPHA+U(I)*BETA
    2 YDD(I+3,1)=R(I)*GAMMA+U(I)*ALPHA
```

```
C  DECIDE WHETHER WDD IS REQUIRED AT THIS TIME.
   21 IF(N.LE.0) RETURN
C  COMPUTE ADDITIONAL QUANTITIES COMMON TO MANY COMPONENTS OF WDD.
      DELTA=-3.*ALPHA*R2
      EPSIL=-BETA*U2
      ZETA=-5.*GAMMA*R2
C  COMPUTE THE MATRIX B NEEDED IN THE MATRIX EQUATION  WDD=B*W.
      DO 3 J=1,3
      RRJ=DELTA*R(J)
      RUJ=EPSIL*U(J)
      URJ=ZETA*R(J)+DELTA*U(J)
      DO 3 I=1,3
      IF (I.EQ. J)  GO TO 7
      B(I,J)=R(I)*RRJ
      B(I,J+3)=U(I)*RUJ
      B(I+3,J)=R(I)*URJ+U(I)*RRJ
      GO TO 3
    7 B(I,J)=R(I)*RRJ+ALPHA
      B(I,J+3)=U(I)*RUJ+BETA
      B(I+3,J)=R(I)*URJ+U(I)*RRJ+GAMMA
    3 B(I+3,J+3)=B(I,J)
C  PERFORM THE MATRIX MULTIPLICATION B*W TO GET WDD.
      DO 5 I=1,6
       DO 5 J=2,LEG6
      SUM=0.
      DO 4 K=1,6
    4 SUM=SUM+B(I,K)*Y(K,J)
    5 YDD(I,J)=SUM
      IF(LEG.LE.1) RETURN
      PRDDM=BETA/AM1
       DO 6 J=8,LEG6
      RDDMB=PRDDM*(ATP(J-7,3)-ATP(J-6,3))
       DO 6 I=1,3
C CALCULATE PORTION OF WDD DEPENDING ON DISCRETE CHANGES IN MASS RATE
  6   YDD(I,J)=YDD(I,J)+RDDMB*U(I)
      RETURN
      END



       SUBROUTINE COAST(PHI,DPHI,UK,LEG,ATP,NO)
      IMPLICIT REAL*8 (A-H,O-Z)
C THIS ROUTINE PROPAGATES STATE, COSTATE AND THE PARTIALS OVER COASTING
C ARCS USING A CLOSED FORM UNIVERSAL VARIABLE SOLUTION TO THE TWO-BODY
C PROBLEM. PHI = PARTIAL OF STATE(COSTATE) AT END OF ARC WITH RESPECT TO
C INITIAL STATE(COSTATE). DPHI= PARTIAL OF FINAL COSTATE WITH RESPECT TO
C INITIAL STATE. UK IS UNIVERSAL GRAVIATIONAL CONSTANT. LEG TELLS WHICH
C ARC PROPAGATING. ATP ARRAY CONTAINS SWITCHING TIMES AND MASS DATA.
C IF NO EQUALS ZERO ONLY STATE AND COSTATE PROPAGATED.
       COMMON/WCOAST/PSY,ALPHA,FT
       COMMON/CCOAST/ANN(2,2),BNN(3,3),XX0(6,6)
     1,DAN(2,2),DBNN(3,3),DXX0(6,6)
      COMMON/ACOAST/R0(3),V0(3),DR0(3),DV0(3),R(3),V(3),DR(3),DV(3)
C R0,V0    STATE AT START OF COAST     ,  R,V    STATE AT END OF COAST
C DR0,DV0  COSTATE AT START OF COAST   ,  DR,DV  COSTATE AT END OF COAST
```

```
      DIMENSION PHI(6,6),DPHI(6,6),ATP(7,4),H0(3)
C        TIME OF COAST
      T=ATP(LEG+1,1)-ATP(LEG,1)
       JUMP=0
       RM0=DSQRT(R0(1)*R0(1)+R0(2)* R0(2)+R0(3)*R0(3))
      DRM0=(R0(1)*DR0(1)+R0(2)*DR0(2)+R0(3)*DR0(3))/RM0
      SIG0=R0(1)*V0(1)+R0(2)*V0(2)+R0(3)*V0(3)
      DSIG0=(V0(1)*DR0(1)+V0(2)*DR0(2)+V0(3)*DR0(3)+R0(1)*DV0(1)
     1+R0(2)*DV0(2)+R0(3)*DV0(3))
      ALPHA=V0(1)*V0(1)+V0(2)*V0(2)+V0(3)*V0(3)-2.*UK/RM0
      H0(1)=R0(2)*V0(3)-R0(3)*V0(2)
      H0(2)=R0(3)*V0(1)-R0(1)*V0(3)
      H0(3)=R0(1)*V0(2)-R0(2)*V0(1)
      P0=(H0(1)*H0(1)+H0(2)*H0(2)+H0(3)*H0(3))/UK
       PSY=T/P0
      ALPSQ=DSQRT(-ALPHA)
   83 ALPSY=PSY*ALPSQ
      S0=DCOS(ALPSY)
      S1=DSIN(ALPSY)/ALPSQ
C ITERATIVE SOLUTION FOR UNIVERSAL VARIABLE
       S2=(S0-1.0)/ALPHA
       S3=(S1-PSY)/ALPHA
       FT=RM0*S1+SIG0*S2+UK*S3
       RM=RM0*S0+SIG0*S1+UK*S2
       IF(JUMP.EQ.1) GO TO 84
       PSY=PSY+(T-FT)/RM
       IF(DABS(T-FT).GE.DABS(T)*1.D-5) GO TO 83
       JUMP=1
       GO TO 83
  84   FM1=-UK*S2/RM0
      F=1.0+FM1
       FD=-UK*S1/(RM*RM0)
       G=FT-UK*S3
       GDM1=-UK*S2/RM
       GD=1.0+GDM1
      UKR3=UK/(RM*RM*RM)
       UKR03=UK/(RM0*RM0*RM0)
      DALPH=2.0*(V0(1)*DV0(1)+V0(2)*DV0(2)+V0(3)*DV0(3)+UKR03*(
     1R0(1)*DR0(1)+R0(2)*DR0(2)+R0(3)*DR0(3)))
       DAPA=DALPH/ALPHA
       DAPA2=DAPA/ALPHA
      DPSY=-(DRM0*S1+DSIG0*S2+RM0*(PSY*S0-S1)*DAPA*.5+SIG0*(PSY*S1*.5-
     1S2)*DAPA+UK*(PSY-1.5*S1+PSY*S0*.5)*DAPA2)/RM
      DS0=(ALPHA*DPSY+.5*PSY*DALPH)*S1
      DS1=S0*DPSY+(PSY*S0-S1)*DAPA*.5
       DS2=S1*DPSY+(.5*PSY*S1-S2)*DAPA
      DS3=S2*DPSY+(PSY-1.5*S1+.5*PSY*S0)*DAPA2
      S4=(S2-PSY*PSY*.5)/ALPHA
      DS4=S3*DPSY+(PSY*PSY*.5-2.0*S2+.5*PSY*S1)*DAPA2
      S5=(S3-PSY*PSY*PSY/6.0)/ALPHA
      DS5=S4*DPSY+(PSY*PSY*PSY/6.0+(2.0*PSY-2.5*S1+.5*PSY*S0)/ALPHA)
     1*DAPA2
      U=S2*FT+UK*(PSY*S4-3.0*S5)
       DU=DS2*FT+UK*(DPSY*S4+PSY*DS4-3.0*DS5)
      DRM=S0*DRM0+DS0*RM0+S1*DSIG0+DS1*SIG0+UK*DS2
```

```
      DF=(-UK*DS2-FM1*DRM0)/RM0
      DG=-UK*DS3
      DGD=(-UK*DS2-GDM1*DRM)/RM
      R01=RM0*RM
      DR01=RM*DRM0+DRM*RM0
      DFD=(-UK*DS1-FD*DR01)/R01
      DO 4 I=1,3
      DR(I)=R0(I)*DF+V0(I)*DG+DR0(I)*F+DV0(I)*G
      R(I)=R0(I)*F+V0(I)*G
      DV(I)=R0(I)*DFD+V0(I)*DGD+DR0(I)*FD+DV0(I)*GD
4     V(I)=R0(I)*FD+V0(I)*GD
 R,V STATE AT END OF COAST
 DR,DV COSTATE AT END OF COAST
      IF(NO.EQ.0) RETURN
 CALCULATION OF PARTIALS
      DUKR3=-3.0*UKR3*DRM/RM
      DUR03=-3.0*UKR03*DRM0/RM0
      S1R0=S1/RM0
      DS1R0=(DS1-S1R0*DRM0)/RM0
      S1R=S1/RM
      DS1R=(DS1-S1R*DRM)/RM
      R02=1.0/(RM0*RM0)
      R2=1.0/(RM*RM)
      UUK03=-U*UKR03
      DUUK3=-DU*UKR03-U*DUR03
      ANN(1,1)=-FD*S1R0-FM1*R02
      ANN(1,2)=-FD*S2
      ANN(2,1)=FM1*S1R0+UUK03
      ANN(2,2)=FM1*S2
      DUMM1=ANN(1,1)
      DAN(1,1)=-FD*DS1R0-DFD*S1R0+UKR03*DS2+DUR03*S2
      DUMMY=DAN(1,1)
      DAN(1,2)=-DFD*S2-FD*DS2
      DAN(2,1)=FM1*DS1R0+DF*S1R0+DUUK3
      DAN(2,2)=FM1*DS2+DF*S2
      CALL AMULT
      DO 5 I=1,3
      DO 5 J=1,3
      DXX0(I,J)=DBNN(I,J)
5     XX0(I,J)=BNN(I,J)
      DO 6 I=1,3
      DXX0(I,I)=DXX0(I,I)+DF
6     XX0(I,I)=XX0(I,I)+F
      ANN(1,1)=ANN(1,2)
      ANN(2,1)=ANN(2,2)
      ANN(1,2)=-GDM1*S2
      ANN(2,2)=G*S2-U
      DAN(1,1)=DAN(1,2)
      DAN(2,1)=DAN(2,2)
      DAN(1,2)=-GDM1*DS2-DGD*S2
      DAN(2,2)=-DU+DG*S2+G*DS2
      CALL AMULT
      DO 7 I=1,3
      DO 7 J=1,3
      J3=J+3
```

```
      DXXO(I,J3)=DBNN(I,J)                                              SWI01260
 7    XXO(I,J3)=BNN(I,J)                                                SWI01270
      DO 8 I=1,3                                                        SWI01280
      I3=I+3                                                            SWI01290
      DXXO(I,I3)=DXXO(I,I3)+DG                                          SWI01300
 8    XXO(I,I3)=XXO(I,I3)+G                                             SWI01310
      ANN(2,1)=-ANN(1,1)                                                SWI01320
      ANN(2,2)=-ANN(1,2)                                                SWI01330
      ANN(1,1)=-FD*S1R-GDM1*R2                                          SWI01340
      ANN(1,2)=U*UKR3-GDM1*S1R                                          SWI01350
      DAN(2,1)=-DAN(1,1)                                                SWI01360
      DAN(2,2)=-DAN(1,2)                                                SWI01370
      DAN(1,1)=-DFD*S1R-FD*DS1R+UKR3*DS2+DUKR3*S2                       SWI01380
      DAN(1,2)=-GDM1*DS1R-DGD*S1R+DU*UKR3+U*DUKR3                       SWI01390
      CALL AMULT                                                        SWI01400
      DO 9 I=1,3                                                        SWI01410
     I3=I+3                                                             SWI01420
      DO 9 J=1,3                                                        SWI01430
      J3=J+3                                                            SWI01440
      DXXO(I3,J3)=DBNN(I,J)                                             SWI01450
 9    XXO(I3,J3)=BNN(I,J)                                               SWI01460
      DO 10 I=4,6                                                       SWI01470
      DXXO(I,I)=DXXO(I,I)+DGD                                           SWI01480
 10  XXO(I,I)=XXO(I,I)+GD                                               SWI01490
      ANN(1,2)=ANN(1,1)                                                 SWI01500
      ANN(2,2)=ANN(2,1)                                                 SWI01510
      ANN(2,1)=-DUMM1                                                   SWI01520
     ANN(1,1)=-FD*(SO/RO1+R2+RO2)-UUKO3*UKR3                            SWI01530
      DAN(1,2)=DAN(1,1)                                                 SWI01540
      DAN(2,2)=DAN(2,1)                                                 SWI01550
      DAN(2,1)=-DUMMY                                                   SWI01560
     DAN(1,1)=-UUKO3*DUKR3-DUUK3*UKR3-DFD*(SO/RO1+R2+RO2)-FD*((DSO-SO*  SWI01570
     1DRO1/RO1)/RO1-2.0*(R2*DRM/RM+RO2*DRMO/RMO))                       SWI01580
      CALL AMULT                                                        SWI01590
      DO 11 I=1,3                                                       SWI01600
     I3=I+3                                                             SWI01610
      DO 11 J=1,3                                                       SWI01620
      DXXO(I3,J)=DBNN(I,J)                                              SWI01630
 11   XXO(I3,J)=BNN(I,J)                                                SWI01640
      DO 12 I=1,3                                                       SWI01650
      I3=I+3                                                            SWI01660
     DXXO(I3,I)=DXXO(I3,I)+DFD                                          SWI01670
 12    XXO(I3,I)=XXO(I3,I)+FD                                           SWI01680
C       XXO PARTIAL OF XF WITH RESPECT TO XO                            SWI01690
C      DXXO PARTIAL OF QF WITH RESPECT TO XO                            SWI01700
      DO 50 I=1,6                                                       SWI01710
      DO 50 J=1,6                                                       SWI01720
      PHI(I,J)=XXO(I,J)                                                 SWI01730
 50   DPHI(I,J)=DXXO(I,J)                                               SWI01740
      RETURN                                                            SWI01750
      END                                                               SWI01760
      SUBROUTINE AMULT                                                  SWI01770
     IMPLICIT REAL*8(A-H,O-Z)                                           SWI01780
C SPECIAL PURPOSE MATRIX MULTIPLICATION ROUTINE                         SWI01790
      COMMON/CCOAST/ANN(2,2),BNN(3,3),XXO(6,6)                          SWI01800
```

```
     1,DAN(2,2),DBNN(3,3),DXX0(6,6)
      COMMON/ACOAST/R0(3),V0(3),DR0(3),DV0(3),R(3),V(3),DR(3),DV(3)
      DIMENSION DA(3,2),A(3,2)
      DO 1 I=1,3
      DO 1 J=1,2
      DA(I,J)=DR(I)*ANN(1,J)+DV(I)*ANN(2,J)+R(I)*DAN(1,J)+V(I)*DAN(2,J)
 1    A(I,J)=ANN(1,J)*R(I)+ANN(2,J)*V(I)
      DO 2 I=1,3
      DO 2 J=1,3
      DBNN(I,J)=A(I,1)*DR0(J)+A(I,2)*DV0(J)+DA(I,1)*R0(J)+DA(I,2)*V0(J)
 2    BNN(I,J)=A(I,1)*R0(J)+A(I,2)*V0(J)
      RETURN
      END



      SUBROUTINE ADJUST(Q0,E,Z,DU,DUDT,LEGMAX,ATP)
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/WADJ/A(8),CK
      DIMENSION Q0(6),E(12,13),Z(12,12),ATP(7,2)
C SOLUTION OF SIMULTANEOUS EQUATIONS
      CALL SOLVE(E,LEGMAX)
      L7=LEGMAX+7
      DU=DSQRT(E(1,L7)*E(1,L7)+E(2,L7)*E(2,L7)+E(3,L7)*E(3,L7))
      DUD=DSQRT(E(4,L7)*E(4,L7)+E(5,L7)*E(5,L7)+E(6,L7)*E(6,L7))
      DUDT=DUD*(ATP(LEGMAX+1,1)-ATP(1,1))
      A(1)=.2/DU
      A(2)=.0003/DUD
      A(3)=1.0
      IF(ATP(1,4).NE.0) A(3)=(.5*(ATP(2,1)-ATP(1,1))/DABS(E(7,L7)))
      CK=DMIN1(1.D0,A(1),A(2),A(3))
C CALCULATION OF BOUND(CK) ON CHANGES ALLOWED IN INITIAL COSTATE
C AND SWITCHING TIMES
      DO 8 I=2,LEGMAX
      I2=I+2
      A(I2)=(.5*(ATP(I+1,1)-ATP(I,1))/DABS(E(I+6,L7)-E(I+5,L7)))
 8    CK=DMIN1(CK,A(I2))
C CALCULATION OF NEW INITIAL COSTATE AND SWITCHING TIMES
      DO 6 I=1,6
      ATP(I+1,1)=ATP(I+1,1)+CK*E(I+6,L7)
 6    Q0(I)=Q0(I)+CK*E(I,L7)
      UM=DSQRT(Q0(1)*Q0(1)+Q0(2)*Q0(2)+Q0(3)*Q0(3))
      DO 7 I=1,6
 7    Q0(I)=Q0(I)/UM
      RETURN
      END



      SUBROUTINE SOLVE(A,LEGMAX)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(12,13)
      L6=6+LEGMAX
      L7=7+LEGMAX
      DO 6 N=1,L6
```

```
      IBIG=N
       DO 1 I=N,L6
      IF( DABS( A(I,N) ).GT. DABS(A(IBIG,N)))  IBIG=I
    1 CONTINUE
      IF (IBIG.EQ.N) GO TO 3
       DO 2 J=N,L7
      Q=A(N,J)
      A(N,J)=A(IBIG,J)
    2 A(IBIG,J)=Q
   3   DO 5 I=1,L6
      IF(I.EQ.N) GO TO 5
      Q=A(I,N)/A(N,N)
      M=N+1
       DO 4 K=M,L7
    4 A(I,K)=A(I,K)-Q*A(N,K)
    5 CONTINUE
    6 CONTINUE
       DO 7 I=1,L6
   7   A(I,L7)=A(I,L7)/A(I,I)
      RETURN
      END


       SUBROUTINE BVEVAL(XF,QF,Z,C,E,DC)
      IMPLICIT REAL*8(A-H,O-Z)
C
C  THIS VERSION DEALS WITH A FIVE-CONSTRAINT RIGHT-END BOUNDARY-VALUE
C  PROBLEM WHERE THE FIVE CONSTRAINED FUNCTIONS ARE THE THREE COMPON-
C  ENTS OF THE ORBITAL ANGULAR VELOCITY VECTOR (R CROSS V) AND THE FIRST
C  TWO COMPONENTS OF THE VECTOR WHOSE DIRECTION IS THE DIRECTION OF
C  PERICENTER AND WHOSE MAGNITUDE IS THE ORBITAL ECCENTRICITY.  THUS, IN
C  EFFECT, ALL OF THE SIX CLASSICAL ORBITAL ELEMENTS ARE CONSTRAINED
C  EXCEPT THE MEAN ANOMALY, WHICH IS FREE.
C
      COMMON/CCPINJ/UK,ATP(7,4),AI,LEG,ITBURN
       DIMENSION XF(6),C(12),DC(12),G(7,6),Z(12,12),E(12,13),R(3),V(3)
     1,QF(6),DUMMY(12)
       LEG6=6+LEG
      DO 1 I=1,3
      R(I)=XF(I)
    1 V(I)=XF(I+3)
      R2=R(1)**2+R(2)**2+R(3)**2
      G(1,2)=V(3)
      G(1,3)=-V(2)
      G(2,3)=V(1)
      G(1,5)=-R(3)
      G(1,6)=R(2)
      G(2,6)=-R(1)
      RM=DSQRT(R2)
      R3=RM*R2
       C1=-1.0/RM+(V(1)**2+V(2)**2+V(3)**2)/UK
       C2=-(R(1)*V(1)+R(2)*V(2)+R(3)*V(3))/UK
      DO 4 I=1,3
      DO 3 J=1,3
```

```
      IF(I.LE.J) GO TO 2                                                 BVE00320
      G(I,J)=-G(J,I)                                                     BVE00330
      G(I,J+3)=-G(J,I+3)                                                 BVE00340
    2 G(I+3,J)=R(I)*R(J)/R3-V(I)*V(J)/UK                                 BVE00350
    3 G(I+3,J+3)=(R(I)*V(J)*2.-V(I)*R(J))/UK                             BVE00360
      G(I,I)=0.                                                          BVE00370
      G(I,I+3)=0.                                                        BVE00380
      G(I+3,I)=G(I+3,I)+C1                                               BVE00390
    4 G(I+3,I+3)=G(I+3,I+3)+C2                                           BVE00400
      DO 5 I=1,3                                                         BVE00410
      DC(I)=0.                                                           BVE00420
      DO 5 J=1,3                                                         BVE00430
    5 DC(I)=DC(I)+G(I,J)*R(J)                                            BVE00440
       DO 8 I=1,2                                                        BVE00450
      SUM=0.                                                             BVE00460
      DO 7 J=1,3                                                         BVE00470
    7 SUM=SUM+G(I,J)*DC(J)                                               BVE00480
    8 DC(I+3)=C(I+3)+R(I)/RM+SUM/UK                                      BVE00490
      DO 9 I=1,3                                                         BVE00500
9       DC(I)=C(I)-DC(I)                                                 BVE00510
        DO 10 I=1,5                                                      BVE00520
        DO 10 J=1,LEG6                                                   BVE00530
      E(I,J)=0.                                                          BVE00540
      DO 10 K=1,6                                                        BVE00550
   10 E(I,J)=E(I,J)+G(I,K)*Z(K,J)                                        BVE00560
       RS=XF(1)*QF(1)+XF(2)*QF(2)+XF(3)*QF(3)                            BVE00570
       C3=-UK/R3                                                         BVE00580
       C4=-3.0*C3*RS/R2                                                  BVE00590
       DC(6)=              XF(4)*QF(4)+XF(5)*QF(5)+XF(6)*QF(6)-C3*RS     BVE00600
       DO 16 I=1,3                                                       BVE00610
       DUMMY(I)=-C3*QF(I)-C4*XF(I)                                       BVE00620
       DUMMY(I+3)=QF(I+3)                                                BVE00630
       DUMMY(I+6)=-C3*XF(I)                                              BVE00640
   16  DUMMY(I+9)=XF(I+3)                                                BVE00650
       DO 17 J=1,LEG6                                                    BVE00660
       DO 17 K=1,12                                                      BVE00670
   17  E(6,J)=-DUMMY(K)*Z(K,J)+E(6,J)                                    BVE00680
       RETURN                                                            BVE00690
       END                                                               BVE00700


       SUBROUTINE BVEVAL(XF,QF,Z,C,E,DC)                                 BVE00010
       IMPLICIT REAL*8 (A-H,O-Z)                                         BVE00020
                                                                         BVE00030
      THIS VERSION OF BVEVAL IS FOR 6 CONSTRAINT RENDEZVOUS MISSIONS     BVE00040
      THE FINAL ORBIT IS SPECIFIED BY A RADIUS , VELOCITY AND TIME       BVE0005C
      CONTAINED AS INPUT CONSTANTS IN THE C VECTOR                       BVE00060
                                                                         BVE00070
      COMMON/CCPINJ/UK,ATP(7,4),AM,LEG,ITBURN                            BVE00080
      COMMON/WIN/PLANS(54),NOUT,LOGIC                                    BVE00090
      DIMENSION XF(6),QF(6),Z(12,12),C(12),E(12,13),DC(12),R0(3),V0(3)   BVE00100
     1,H0(3),V(3),R(3),E1(3)                                             BVE00110
      PROPAGATE RADIUS AND VELOCITY OF FINAL ORBIT TO FINAL TIME         BVE00120
       T=ATP(LEG+1,1)-C(7)                                               BVE00130
```

```
      DO 40 I=1,3
      RO(I)=C(I)
 40   VO(I)=C(I+3)
      JUMP=0
      RMO=DSQRT(RO(1)*RO(1)+RO(2)* RO(2)+RO(3)*RO(3))
      SIGO=RO(1)*VO(1)+RO(2)*VO(2)+RO(3)*VO(3)
      ALPHA=VO(1)*VO(1)+VO(2)*VO(2)+VO(3)*VO(3)-2.*UK/RMO
      HO(1)=RO(2)*VO(3)-RO(3)*VO(2)
      HO(2)=RO(3)*VO(1)-RO(1)*VO(3)
      HO(3)=RO(1)*VO(2)-RO(2)*VO(1)
      PO=(HO(1)*HO(1)+HO(2)*HO(2)+HO(3)*HO(3))/UK
      PSY=T/PO
      ALPSQ = DSQRT(-ALPHA)
 83   ALPSY=PSY*ALPSQ
      SO=DCOS(ALPSY)
      S1=DSIN(ALPSY)/ALPSQ
C ITERATIVE SOLUTION FOR UNIVERSAL VARIABLE
      S2=(SO-1.0)/ALPHA
      S3=(S1-PSY)/ALPHA
      FT=RMO*S1+SIGO*S2+UK*S3
      RM=RMO*SO+SIGO*S1+UK*S2
      IF(JUMP.EQ.1) GO TO 84
      PSY=PSY+(T-FT)/RM
      IF(DABS(T-FT).GE.DABS(T)*1.D-5) GO TO 83
      JUMP=1
      GO TO 83
 84   CONTINUE
      FM1=-UK*S2/RMO
      F=1.0+FM1
      FD=-UK*S1/(RM*RMO)
      G=FT-UK*S3
      GDM1=-UK*S2/RM
      GD=1.0+GDM1
      DO 4 I=1,3
      R(I)=RO(I)*F+VO(I)*G
      V(I)=RO(I)*FD+VO(I)*GD
      DC(I)=R(I)-XF(I)
 4    DC(I+3)=V(I)-XF(I+3)
      R2T=R(1)**2+R(2)**2+R(3)**2
      R3T=R2T*DSQRT(R2T)
      LEG5=LEG+5
      DO 5 I=1,6
      DO 5 J=1,LEG5
 5    E(I,J)=Z(I,J)
      DO 6 I=1,3
      E(I,LEG5+1)=Z(I,LEG5+1)-V(I)
 6    E(I+3,LEG5+1)=Z(I+3,LEG5+1)+R(I)*UK/R3T
      WRITE(NOUT,100) R,V
 100  FORMAT(20X,42HTARGET VEHICLE FINAL POSITION AND VELOCITY,/25X,
     12HR ,3E14.6,5X,2HV ,3E14.6)
      IF(LOGIC.GT.0) RETURN
      LOGIC=1
      E1(1)=-(RO(1)/RMO+(HO(2)*VO(3)-HO(3)*VO(2))/UK)
      E1(2)=-(RO(2)/RMO+(HO(3)*VO(1)-HO(1)*VO(3))/UK)
      E1(3)=-(RO(3)/RMO+(HO(1)*VO(2)-HO(2)*VO(1))/UK)
```

```
      EMAG=DSQRT(E1(1)**2+E1(2)**2+E1(3)**2)                            BVE00690
      HMAG=DSQRT(P0*UK)                                                 BVE00700
     AAXIS=-UK/ALPHA                                                    BVE00710
     ENERGY=.5*ALPHA                                                    BVE00720
     PERIOD=(6.2831853)*DSQRT(DABS(AAXIS**3/UK))                        BVE00730
      RMIN=AAXIS*(1.0-EMAG)                                             BVE00740
      RMAX=AAXIS*(1.0+EMAG)                                             BVE00750
     WRITE(NOUT,101)AAXIS,RMIN,RMAX,ENERGY,PERIOD,HMAG,H0,EMAG,E1       BVE00760
 101 FORMAT(22X,27HTARGET ORBIT SPECIFICATIONS,/25X,15HSEMIMAJOR AXIS=,BVE00770
    1E14.6,1X5HRMIN=,E14.6,1X5HRMAX=,E14.6,1X7HENERGY=,E14.6,/25X,      BVE00780
    27HPERIOD=,E14.6,1X5HHMAG=,E14.6,1X8HH VECTOR,3E14.6,/25X5HEMAG=,   BVE00790
    3E14.6,1X8HE VECTOR,3E14.6)                                         BVE00800
      RETURN                                                            BVE00810
      END                                                               BVE00820
```

APPENDIX II-1

INPUT FILE and OUTPUT LISTING
for 5-CONSTRAINT MISSION

```
 1
    TEST CASE NUMBER 2 FOR DOUBLE PRECISION DECK
         5-CONSTRAINT , 44 DEGREE PLANE CHANGE CASE RUN ON 7/7/69
          APRIL 28,1970
398601.5  12644651. 100.
4551.308594719.8398425.05763245.5990610 -5.4170895-.0118389
.4601788  -.8868545 .0415273  -.0004394 -.0010504 -.0004081
65248.406 62230.797 -93156.688
 410
934.      0.0       0.0       0.0
2047.6868 0.0       22384.406 92986.438
2302.8677 0.0       0.0       0.0
21032.055 0.0       22384.406 92986.438
21150.852 0.0       0.0       0.0
```

```
CASE NUMBER  1

   TEST CASE NUMBER 2 FOR DOUBLE PRECISION DECK
        5-CONSTRAINT , 44 DEGREE PLANE CHANGE CASE RUN ON 7/7/69
         APRIL 28,1970

GRAVITATIONAL CONSTANT= 398601.50 INITIAL MASS=  0.12644651D 08 MAX INTEGRATION STEP=   100.000
MAX NUMBER OF ITERATIONS= 10 NUMBER OF SEPERATE ARCS=  4

                                       ATP ARRAY

      TIME               DELTA MASS           MASS RATE              THRUST

    0.93400000D 03        0.0                  0.0                    0.0
    0.20476868D 04        0.0                  0.22384406D 05         0.92986438D 05
    0.23028677D 04        0.0                  0.0                    0.0
    0.21032055D 05        0.0                  0.22384406D 05         0.92986438D 05
    0.21150852D 05        0.0                  0.0                    0.0

INITIAL STATE X0      4551.3085900     4719.8398400      25.0576324       5.5990610      -5.4170895      -0.0118389
   ESTIMATED Q0         0.4601788       -0.8868545        0.0415273      -0.0004394      -0.0010504      -0.0004081

DESIRED FINAL C  0.65248406D 05  0.62230797D 05 -0.93156688D 05  0.0          0.0          0.0          0.0

ITERATION NUMBER    1

                 COAST ARC
                      LEG= 1 STATE AT END   0.566318D 04 -0.326767D 04 -0.356783D 01 -0.391783D 01 -0.675935D 01 -0.318202D-01
                           COSTATE AT END  -0.722406D 00 -0.129057D 01 -0.323877D 00 -0.114317D-02  0.648873D-03 -0.147330D-03
                           PSY=  0.170086D 00     ALPHA= -0.608893D 02      CALCULATED COAST TIME=  0.111369D 04
                      SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653121D 04 RMAX=  0.656146D 04 ENERGY= -0.304446D 02
                      PERIOD=  0.527118D 04 HMAG=  0.510819D 05 H VECTOR  0.798617D 02  0.194182D 03 -0.510815D 05
                      EMAG=  0.231029D-02 E VECTOR  0.825497D-04 -0.230879D-02 -0.864761D-05 RMAG=  0.653829D 04
                 BURN ARC
                      LEG= 2 STATE AT END   0.426351D 04 -0.504586D 04 -0.745324D 02 -0.717529D 01 -0.721793D 01 -0.583854D 00
                           COSTATE AT END  -0.969136D 00 -0.107409D 01 -0.346046D 00 -0.756949D-03  0.100789D-02 -0.259835D-04
                           MASS AT END OF LEG=  0.693258D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   3
                 COAST ARC
                      LEG= 3 STATE AT END  -0.317618D 05  0.259626D 05  0.302691D 02  0.111210D 01  0.119975D 01  0.941506D-01
                           COSTATE AT END  -0.625811D-01 -0.322132D 00  0.158030D 01  0.278258D-04 -0.646041D-05  0.100800D-04
                           PSY=  0.761753D 00     ALPHA= -0.167481D 02      CALCULATED COAST TIME=  0.187292D 05
                      SEMIMAJOR AXIS=  0.237998D 05 RMIN=  0.654657D 04 RMAX=  0.410529D 05 ENERGY= -0.837407D 01
                      PERIOD=  0.365400D 05 HMAG=  0.670907D 05 H VECTOR  0.240808D 04  0.302406D 04 -0.669792D 05
                      EMAG=  0.724931D 00 E VECTOR  0.571933D 00 -0.445440D 00  0.451211D-03 RMAG=  0.410228D 05
                 BURN ARC
                      LEG= 4 STATE AT END  -0.316326D 05  0.260821D 05  0.148952D 03  0.105819D 01  0.780387D 00  0.206199D 01
                           COSTATE AT END  -0.592583D-01 -0.322899D 00  0.158143D 01  0.281141D-04 -0.644141D-05  0.899433D-05
                           MASS AT END OF LEG=  0.427338D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   2
                   RESULTANT ORBIT SPECIFICATIONS
                      SEMIMAJOR AXIS=  0.296053D 05 RMIN=  0.176885D 05 RMAX=  0.415220D 05 ENERGY= -0.673193D 01
                      PERIOD=  0.506949D 05 HMAG=  0.994420D 05 H VECTOR  0.536648D 05  0.653837D 05 -0.522855D 05
                      EMAG=  0.402521D 00 E VECTOR  0.330946D 00 -0.219748D 00  0.648788D-01 RMAG=  0.409990D 05
                 TOTAL BURN TIME=  0.373978D 03 ARC TIMES   0.111369D 04  0.255181D 03  0.187292D 05  0.118797D 03

                      DC    0.115836D 05 -0.315293D 04 -0.408712D 05 -0.330946D 00  0.219748D 00  0.676767D-05
                          -0.291283D-03 -0.126509D 00  0.191553D-04  0.0            0.0            0.0
                      DETERMINANT OF E=  0.469171D 06 DIAGONAL OF E  0.343838D 06  0.580557D 06  0.454408D 04 -0.747924D 03
                       -0.448433D 03  0.376413D 03 -0.115034D-01  0.291542D-04 -0.440405D-03  0.277357D-07
                      DU=  0.713125D-01 DUDT=  0.208593D 01 CK=  0.100000D 01 EVT=  0.100000D-07
                      CK=MIN OF   0.28946D 01  [illegible]  [illegible]  [illegible]  0.27067D 01  0.52058[illegible]
```

```
            CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
             -0.183289D-01 -0.126825D-01 -0.677398D-01 -0.558381D-04 -0.439104D-04 -0.748311D-04
                           0.785023D 02  0.709078D 02 -0.338887D 04 -0.337746D 04
END OF ITERATION NUMBER    1
          NEW Q0    0.440731D 00 -0.897259D 00 -0.261461D-01 -0.493984D-03 -0.109154D-02 -0.481708D-03
          NEW SWITCH TIMES    0.212619D 04  0.237378D 04  0.176432D 05  0.177734D 05

ITERATION NUMBER    2

             COAST ARC
                LEG= 1 STATE AT END    0.533120D 04 -0.378316D 04 -0.604647D 01 -0.453386D 01 -0.636427D 01 -0.312815D-01
                       COSTATE AT END  -0.992385D 00 -0.129064D 01 -0.405562D 00 -0.130251D-02  0.837206D-03 -0.418768D-04
                       PSY=  0.182094D 00      ALPHA= -0.608893D 02      CALCULATED COAST TIME=  0.119219D 04
                SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653121D 04 RMAX=  0.656146D 04 ENERGY= -0.304446D 02
                PERIOD=  0.527118D 04 HMAG=  0.510819D 05 H VECTOR  0.798617D 02  0.194182D 03 -0.510815D 05
                EMAG=  0.231029D-02 E VECTOR  0.825497D-04 -0.230879D-02 -0.864761D-05 RMAG=  0.653713D 04
             BURN ARC
                LEG= 2 STATE AT END    0.381945D 04 -0.536248D 04 -0.776274D 02 -0.780620D 01 -0.640016D 01 -0.595789D 00
                       COSTATE AT END  -0.126917D 01 -0.102912D 01 -0.398199D 00 -0.898216D-03  0.123767D-02  0.100313D-03
                       MASS AT END OF LEG=  0.710258D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=    3
             COAST ARC
                LEG= 3 STATE AT END   -0.252695D 05  0.253568D 05  0.737217D 02  0.131941D 01  0.129997D 01  0.110184D 00
                       COSTATE AT END   0.229815D 00  0.297048D 00  0.170795D 01  0.355534D-04 -0.393605D-04 -0.759553D-05
                       PSY=  0.708845D 00      ALPHA= -0.188264D 02      CALCULATED COAST TIME=  0.152694D 05
                SEMIMAJOR AXIS=  0.211725D 05 RMIN=  0.654643D 04 RMAX=  0.357986D 05 ENERGY= -0.941319D 01
                PERIOD=  0.306597D 05 HMAG=  0.664230D 05 H VECTOR  0.269808D 04  0.288156D 04 -0.663055D 05
                EMAG=  0.690805D 00 E VECTOR  0.488843D 00 -0.488100D 00 -0.132043D-02 RMAG=  0.357983D 05
             BURN ARC
                LEG= 4 STATE AT END   -0.250786D 05  0.255462D 05  0.215366D 03  0.163953D 01  0.164057D 01  0.225333D 01
                       COSTATE AT END   0.234419D 00  0.291910D 00  0.170683D 01  0.351670D-04 -0.395685D-04 -0.952655D-05
                       MASS AT END OF LEG=  0.418797D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=    2
              RESULTANT ORBIT SPECIFICATIONS
                SEMIMAJOR AXIS=  0.337465D 05 RMIN=  0.316603D 05 RMAX=  0.358327D 05 ENERGY= -0.590582D 01
                PERIOD=  0.616956D 05 HMAG=  0.115758D 06 H VECTOR  0.572109D 05  0.568635D 05 -0.830269D 05
                EMAG=  0.618197D-01 E VECTOR  0.373544D-01 -0.486690D-01 -0.759282D-02 RMAG=  0.357993D 05
             TOTAL BURN TIME=  0.377793D 03 ARC TIMES   0.119219D 04  0.247586D 03  0.152694D 05  0.130207D 03

                DC    0.803755D 04  0.536732D 04 -0.101298D 05 -0.373544D-01  0.486690D-01 -0.118181D-04
                      0.109862D-04 -0.669537D-01 -0.228043D-04  0.0           0.0           0.0
                DETERMINANT OF E=  0.904181D 06 DIAGONAL OF E  0.165663D 06 -0.268231D 06 -0.770109D 03 -0.570899D 03
                  0.348133D 03 -0.200770D 04  0.143213D-01  0.271979D-04  0.383492D-02  0.443291D-07
                DU=  0.464737D-01 DUDT=  0.186750D 01 CK=  0.100000D 01 EVT=  0.100000D-07
                CK=MIN OF    0.43035D 01  0.27051D 01  0.10000D 01  0.14191D 02  0.22269D 01  0.12645D 02

                CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
                 -0.243784D-01 -0.130630D-01  0.373447D-01  0.275731D-04 -0.165447D-04  0.106136D-03
                               0.166599D 02  0.253832D 02  0.345380D 04  0.344866D 04
END OF ITERATION NUMBER    2
          NEW Q0    0.415903D 00 -0.909340D 00  0.111895D-01 -0.465908D-03 -0.110689D-02 -0.375167D-03
          NEW SWITCH TIMES    0.214285D 04  0.239916D 04  0.210970D 05  0.212220D 05
```

```
ITERATION NUMBER    3

                  COAST ARC
                      LEG= 1 STATE AT END    0.525461D 04 -0.388844D 04 -0.656638D 01 -0.465969D 01 -0.627308D 01 -0.311316D-01
                          COSTATE AT END  -0.104533D 01 -0.130990D 01 -0.312801D 00 -0.130499D-02  0.879293D-03 -0.627670D-04
                          PSY=  0.184643D 00      ALPHA= -0.608893D 02      CALCULATED COAST TIME=  0.120885D 04
                      SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653121D 04 RMAX=  0.656146D 04 ENERGY= -0.304446D 02
                      PERIOD=  0.527118D 04 HMAG=  0.510819D 05 H VECTOR  0.798617D 02  0.194182D 03 -0.510815D 05
                      EMAG=  0.231029D-02 E VECTOR  0.825497D-04 -0.230879D-02 -0.864761D-05 RMAG=  0.653689D 04
                  BURN ARC
                      LEG= 2 STATE AT END    0.364010D 04 -0.549503D 04 -0.671915D 02 -0.808135D 01 -0.627309D 01 -0.484941D 00
                          COSTATE AT END  -0.132761D 01 -0.102640D 01 -0.314121D 00 -0.860159D-03  0.128918D-02  0.519496D-04
                          MASS AT END OF LEG=  0.690731D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   3
                  COAST ARC
                      LEG= 3 STATE AT END  -0.305264D 05   0.304263D 05   0.260532D 02   0.102638D 01   0.117974D 01   0.747382D-01
                          COSTATE AT END   0.424335D 00   0.379562D 00   0.158398D 01   0.393361D-04 -0.355595D-04   0.551415D-05
                          PSY=  0.751374D 00      ALPHA= -0.160457D 02      CALCULATED COAST TIME=  0.186978D 05
                      SEMIMAJOR AXIS=  0.248416D 05 RMIN=  0.654756D 04 RMAX=  0.431357D 05 ENERGY= -0.802286D 01
                      PERIOD=  0.389655D 05 HMAG=  0.673190D 05 H VECTOR  0.224327D 04  0.230823D 04 -0.672420D 05
                      EMAG=  0.736428D 00 E VECTOR  0.508820D 00 -0.532379D 00 -0.130029D-02 RMAG=  0.431001D 05
                  BURN ARC
                      LEG= 4 STATE AT END  -0.303657D 05   0.306003D 05   0.151467D 03   0.159281D 01   0.164430D 01   0.210604D 01
                          COSTATE AT END   0.429241D 00   0.375098D 00   0.158461D 01   0.391126D-04 -0.358365D-04   0.452803D-05
                          MASS AT END OF LEG=  0.410795D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   2
                    RESULTANT ORBIT SPECIFICATIONS
                      SEMIMAJOR AXIS=  0.452129D 05 RMIN=  0.429756D 05 RMAX=  0.474502D 05 ENERGY= -0.440805D 01
                      PERIOD=  0.956762D 05 HMAG=  0.134081D 06 H VECTOR  0.641965D 05  0.641927D 05 -0.986707D 05
                      EMAG=  0.494843D-01 E VECTOR -0.418249D-01  0.236565D-01 -0.118215D-01 RMAG=  0.431101D 05
                  TOTAL BURN TIME=  0.381368D 03 ARC TIMES    0.120885D 04  0.256310D 03  0.186978D 05  0.125058D 03

                      DC    0.105187D 04 -0.196191D 04  0.551401D 04  0.418249D-01 -0.236565D-01  0.636164D-05
                         -0.795336D-05  0.240634D-01  0.143150D-04  0.0            0.0            0.0
                      DETERMINANT OF E=  0.218825D 07 DIAGONAL OF E  0.989428D 05  0.104159D 07 -0.494848D 03 -0.845924D 03
                       -0.302159D 04 -0.173055D 04 -0.221775D-01  0.124779D-04 -0.119960D-02  0.292216D-07
                      DU=  0.219740D-02 DUDT=  0.474445D 00 CK=  0.100000D 01 EVT=  0.100000D-07
                      CK=MIN OF    0.91017D 02  0.12828D 02  0.10000D 01  0.13542D 03  0.57158D 03  0.42119D 03

                      CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
                       -0.612783D-03 -0.305946D-03 -0.208793D-02 -0.193894D-05 -0.307218D-05 -0.231016D-04
                                    0.365356D 01  0.270719D 01 -0.136491D 02 -0.137975D 02
 END OF ITERATION NUMBER    3
              NEW Q0    0.415290D 00 -0.909644D 00  0.910157D-02 -0.467846D-03 -0.110996D-02 -0.398267D-03
              NEW SWITCH TIMES    0.214650D 04  0.240187D 04  0.210833D 05  0.212082D 05
```

```
ITERATION NUMBER    4

                    COAST ARC
                        LEG= 1 STATE AT END    0.523754D 04 -0.391132D 04 -0.668006D 01 -0.468704D 01 -0.625275D 01 -0.310971D-01
                            COSTATE AT END   -0.105682D 01 -0.131006D 01 -0.332533D 00 -0.130896D-02  0.888190D-03 -0.615397D-04
                            PSY=  0.185201D 00      ALPHA= -0.608893D 02      CALCULATED COAST TIME=  0.121250D 04
                        SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653121D 04 RMAX=  0.656146D 04 ENERGY= -0.304446D 02
                        PERIOD=  0.527118D 04 HMAG=  0.510819D 05 H VECTOR  0.798617D 02  0.194182D 03 -0.510815D 05
                        EMAG=  0.231029D-02 E VECTOR  0.825497D-04 -0.230879D-02 -0.864761D-05 RMAG=  0.653684D 04
                    BURN ARC
                        LEG= 2 STATE AT END    0.362387D 04 -0.550437D 04 -0.697098D 02 -0.809232D 01 -0.623232D 01 -0.507112D 00
                            COSTATE AT END   -0.133891D 01 -0.102537D 01 -0.332682D 00 -0.863044D-03  0.129790D-02  0.597602D-04
                            MASS AT END OF LEG=  0.692849D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=    3
                    COAST ARC
                        LEG= 3 STATE AT END   -0.290933D 05  0.304724D 05  0.688227D 02  0.114114D 01  0.111211D 01  0.798564D-01
                            COSTATE AT END    0.362727D 00  0.343209D 00  0.164449D 01  0.337839D-04 -0.349777D-04  0.235147D-06
                            PSY=  0.756702D 00      ALPHA= -0.163768D 02      CALCULATED COAST TIME=  0.186815D 05
                        SEMIMAJOR AXIS=  0.243394D 05 RMIN=  0.654735D 04 RMAX=  0.421315D 05 ENERGY= -0.818840D 01
                        PERIOD=  0.377899D 05 HMAG=  0.672126D 05 H VECTOR  0.235687D 04  0.240182D 04 -0.671283D 05
                        EMAG=  0.730998D 00 E VECTOR  0.502779D 00 -0.530632D 00 -0.133323D-02 RMAG=  0.421306D 05
                    BURN ARC
                        LEG= 4 STATE AT END   -0.289236D 05  0.306344D 05  0.196081D 03  0.161638D 01  0.151750D 01  0.213385D 01
                            COSTATE AT END    0.366931D 00  0.338826D 00  0.164445D 01  0.335405D-04 -0.352042D-04 -0.859687D-06
                            MASS AT END OF LEG=  0.413246D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=    2
                      RESULTANT ORBIT SPECIFICATIONS
                        SEMIMAJOR AXIS=  0.421672D 05 RMIN=  0.421057D 05 RMAX=  0.422287D 05 ENERGY= -0.472644D 01
                        PERIOD=  0.861732D 05 HMAG=  0.129645D 06 H VECTOR  0.650717D 05  0.620356D 05 -0.934083D 05
                        EMAG=  0.145836D-02 E VECTOR -0.120402D-02  0.244341D-04 -0.822535D-03 RMAG=  0.421317D 05
                    TOTAL BURN TIME=  0.380273D 03 ARC TIMES   0.121250D 04  0.255363D 03  0.186815D 05  0.124910D 03

                        DC    0.176703D 03  0.195200D 03  0.251654D 03  0.120402D-02 -0.244341D-04 -0.567036D-06
                           -0.228701D-06  0.304125D-03 -0.338336D-06  0.0            0.0            0.0
                        DETERMINANT OF E=  0.173700D 07 DIAGONAL OF E  0.706414D 05  0.102992D 07 -0.103760D 04  0.579469D 03
                         -0.200050D 04 -0.391689D 03 -0.209508D-01 -0.103926D-04 -0.834149D-02  0.279016D-07
                        DU=  0.196291D-02 DUDT=  0.190827D-01 CK=  0.100000D 01 EVT=  0.100000D-07
                        CK=MIN OF  0.10189D-03  0.31873D-03  0.10000D 01  0.26645D 04  0.19953D 03  0.65427D 03

                        CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
                         -0.302001D-03 -0.118507D-03  0.193592D-02  0.854805D-06  0.391291D-06  0.459566D-07
                                  -0.951165D 00 -0.903245D 00  0.459106D 02  0.460061D 02
END OF ITERATION NUMBER    4
               NEW QO   0.414987D 00 -0.909760D 00  0.110375D-01 -0.466990D-03 -0.110956D-02 -0.398220D-03
               NEW SWITCH TIMES   0.214555D 04  0.240096D 04  0.211293D 05  0.212543D 05
```

```
ITERATION NUMBER    5

                  COAST ARC
                      LEG= 1 STATE AT END    0.524199D 04 -0.390537D 04 -0.665048D 01 -0.467993D 01 -0.625806D 01 -0.311061D-01
                          COSTATE AT END   -0.105476D 01 -0.131074D 01 -0.332188D 00 -0.130886D-02  0.886103D-03 -0.642740D-04
                          PSY=  0.185056D 00      ALPHA= -0.608893D 02       CALCULATED COAST TIME=  0.121155D 04
                      SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653121D 04 RMAX=  0.656146D 04 ENERGY= -0.304446D 02
                      PERIOD=  0.527118D 04 HMAG=  0.510819D 05 H VECTOR  0.798617D 02  0.194182D 03 -0.510815D 05
                      EMAG=  0.231029D-02 E VECTOR  0.825497D-04 -0.230879D-02 -0.864761D-05 RMAG=  0.653685D 04
                  BURN ARC
                      LEG= 2 STATE AT END    0.362978D 04 -0.550056D 04 -0.697194D 02 -0.808573D 01 -0.624170D 01 -0.507535D 00
                          COSTATE AT END   -0.133695D 01 -0.102650D 01 -0.333038D 00 -0.863431D-03  0.129608D-02  0.570480D-04
                          MASS AT END OF LEG=  0.692742D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=    3
                  COAST ARC
                      LEG= 3 STATE AT END   -0.291240D 05  0.304933D 05  0.705079D 02  0.114296D 01  0.110834D 01  0.798441D-01
                          COSTATE AT END    0.358020D 00  0.339462D 00  0.164571D 01  0.334425D-04 -0.347096D-04  0.435675D-06
                          PSY=  0.757596D 00      ALPHA= -0.163647D 02       CALCULATED COAST TIME=  0.187283D 05
                      SEMIMAJOR AXIS=  0.243574D 05 RMIN=  0.654736D 04 RMAX=  0.421674D 05 ENERGY= -0.818235D 01
                      PERIOD=  0.378318D 05 HMAG=  0.672165D 05 H VECTOR  0.235656D 04  0.240597D 04 -0.671321D 05
                      EMAG=  0.731196D 00 E VECTOR  0.503535D 00 -0.530187D 00 -0.132579D-02 RMAG=  0.421670D 05
                  BURN ARC
                      LEG= 4 STATE AT END   -0.289543D 05  0.306547D 05  0.198116D 03  0.161297D 01  0.159974D 01  0.213852D 01
                          COSTATE AT END    0.362185D 00  0.335109D 00  0.164569D 01  0.332020D-04 -0.349324D-04 -0.558000D-06
                          MASS AT END OF LEG=  0.412925D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=    2
                    RESULTANT ORBIT SPECIFICATIONS
                      SEMIMAJOR AXIS=  0.421738D 05 RMIN=  0.421675D 05 RMAX=  0.421802D 05 ENERGY= -0.472570D 01
                      PERIOD=  0.861936D 05 HMAG=  0.129656D 06 H VECTOR  0.652565D 05  0.622387D 05 -0.931584D 05
                      EMAG=  0.150358D-03 E VECTOR -0.110290D-03  0.101773D-03 -0.926277D-05 RMAG=  0.421675D 05
                  TOTAL BURN TIME=  0.380417D 03 ARC TIMES   0.121155D 04  0.255411D 03  0.187283D 05  0.125005D 03

                      DC  -0.811518D 01 -0.794244D 01  0.167323D 01  0.110290D-03 -0.101773D-03  0.271221D-08
                          0.257174D-08  0.853220D-04  0.140462D-09  0.0            0.0            0.0
                      DETERMINANT OF E=  0.174562D 07 DIAGONAL OF E  0.703419D 05  0.104080D 07 -0.102216D 04  0.567671D 03
                       -0.208864D 04 -0.318760D 03 -0.206541D-01 -0.122545D-04 -0.883181D-02  0.276103D-07
                      DU=  0.795462D-05 DUDT=  0.275393D-03 CK=  0.100000D 01 EVT=  0.100000D-07
                      CK=MIN OF   0.25143D 05  0.22136D 05  0.10000D 01  0.19105D 06  0.26600D 05  0.47514D 04

                      CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
                        0.720842D-05  0.329625D-05  0.670297D-06 -0.731178D-08  0.509422D-08 -0.102108D-07
                              -0.216644D-02 -0.149800D-02  0.350532D 00  0.337377D 00
END OF ITERATION NUMBER    5
              NEW QO   0.414994D 00 -0.909757D 00  0.110381D-01 -0.466997D-03 -0.110956D-02 -0.398231D-03
              NEW SWITCH TIMES    0.214555D 04  0.240096D 04  0.211296D 05  0.212546D 05
```

```
ITERATION NUMBER    6

                         COAST ARC
                              LEG= 1 STATE AT END    0.524200D 04 -0.390535D 04 -0.665041D 01 -0.467991D 01 -0.625837D 01 -0.311061D-01
                                   COSTATE AT END  -0.105475D 01 -0.131074D 01 -0.332196D 00 -0.130885D-02  0.886096D-03 -0.642771D-04
                                   PSY=  0.185056D 00      ALPHA= -0.608893D 02      CALCULATED COAST TIME=  0.121155D 04
                              SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653121D 04 RMAX=  0.656146D 04 ENERGY= -0.304446D 02
                              PERIOD=  0.527118D 04 HMAG=  0.510819D 05 H VECTOR  0.798617D 02  0.194182D 03 -0.510815D 05
                              EMAG=  0.231029D-02 E VECTOR  0.825497D-04 -0.230879D-02 -0.864761D-05 RMAG=  0.653685D 04
                         BURN ARC
                              LEG= 2 STATE AT END    0.362978D 04 -0.550056D 04 -0.697216D 02 -0.808573D 01 -0.624172D 01 -0.507553D 00
                                   COSTATE AT END  -0.133694D 01 -0.102649D 01 -0.333047D 00 -0.863428D-03  0.129607D-02  0.570483D-04
                                   MASS AT END OF LEG=  0.692741D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   3
                         COAST ARC
                              LEG= 3 STATE AT END  -0.291242D 05  0.304936D 05  0.705177D 02  0.114297D 01  0.110832D 01  0.798461D-01
                                   COSTATE AT END    0.358071D 00  0.339482D 00  0.164577D 01  0.334445D-04 -0.347111D-04  0.434824D-06
                                   PSY=  0.757602D 00      ALPHA= -0.163646D 02      CALCULATED COAST TIME=  0.187286D 05
                              SEMIMAJOR AXIS=  0.243576D 05 RMIN=  0.654736D 04 RMAX=  0.421678D 05 ENERGY= -0.818228D 01
                              PERIOD=  0.378323D 05 HMAG=  0.672165D 05 H VECTOR  0.235664D 04  0.240606D 04 -0.671321D 05
                              EMAG=  0.731198D 00 E VECTOR  0.503538D 00 -0.530188D 00 -0.132578D-02 RMAG=  0.421674D 05
                         BURN ARC
                              LEG= 4 STATE AT END  -0.289545D 05  0.306550D 05  0.198097D 03  0.161296D 01  0.150966D 01  0.213823D 01
                                   COSTATE AT END    0.362236D 00  0.335129D 00  0.164575D 01  0.332039D-04 -0.349339D-04 -0.658745D-06
                                   MASS AT END OF LEG=  0.412953D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   2
                           RESULTANT ORBIT SPECIFICATIONS
                              SEMIMAJOR AXIS=  0.421680D 05 RMIN=  0.421679D 05 RMAX=  0.421680D 05 ENERGY= -0.472635D 01
                              PERIOD=  0.361756D 05 HMAG=  0.129647D 06 H VECTOR  0.652485D 05  0.622309D 05 -0.931567D 05
                              EMAG=  0.122783D-05 E VECTOR -0.839616D-06  0.895822D-06  0.103491D-07 RMAG=  0.421679D 05
                         TOTAL BURN TIME=  0.380404D 03 ARC TIMES   0.121155D 04  0.255412D 03  0.187286D 05  0.124992D 03
```

TEST CASE NUMBER 2 FOR DOUBLE PRECISION DECK
5-CONSTRAINT , 44 DEGREE PLANE CHANGE CASE RUN ON 7/7/69
APRIL 28,1970

SUMMARY TABLES

ITERATION NUMBER	TOTAL BURN TIME	LENGTH OF BURN AND COAST ARCS				
1	0.3739779D 03	0.1113687D 04	0.2551809D 03	0.1872919D 05	0.1187970D 03
2	0.3777935D 03	0.1192189D 04	0.2475864D 03	0.1526941D 05	0.1302070D 03
3	0.3813682D 03	0.1208849D 04	0.2563098D 03	0.1869783D 05	0.1250584D 03
4	0.3802733D 03	0.1212503D 04	0.2553634D 03	0.1868147D 05	0.1249099D 03
5	0.3804167D 03	0.1211551D 04	0.2554113D 03	0.1872829D 05	0.1250054D 03
6	0.3804042D 03	0.1211549D 04	0.2554120D 03	0.1872864D 05	0.1249922D 03

ITERATION NUMBER	ERROR IN BOUNDARY CONDITIONS-DC(1-8)							
1	-0.115836D 05	-0.315293D 04	-0.408712D 05	-0.330946D 00	0.219748D 00	0.676267D-05	-0.291283D-03	-0.126509D 00
2	0.803755D 04	0.536732D 04	-0.101298D 05	-0.373544D-01	0.486690D-01	-0.118181D-04	0.109862D-04	-0.669537D-01
3	0.105187D 04	-0.196191D 04	0.551401D 04	0.418249D-01	-0.236565D-01	0.636164D-05	-0.795336D-05	0.240634D-01
4	0.176703D 03	0.195200D-03	-0.251654D 03	0.120402D-02	-0.244341D-04	-0.567036D-06	-0.228701D-06	0.304125D-03
5	-0.811518D 01	-0.794244D 01	0.167323D 01	0.110290D-03	-0.101773D-03	0.271221D-08	0.257174D-08	0.853220D-04

ITERATION NUMBER	DC(9-12)				DU	DUDT	CK
1	0.1915531D-04	0.0	0.0	0.0	0.7131254D-01	0.2085934D 01	0.10000000 01
2	-0.2280426D-04	0.0	0.0	0.0	0.4647367D-01	0.1867498D 01	0.10000000 01
3	0.1431501D-04	0.0	0.0	0.0	0.2197400D-02	0.4744453D 00	0.10000000 01
4	-0.3383356D-06	0.0	0.0	0.0	0.1962913D-02	0.1908271D-01	0.10000000 01
5	0.1404625D-09	0.0	0.0	0.0	0.7954616D-05	0.2753928D-03	0.10000000 01

ITERATION NUMBER	NEW QO GENERATED BY PRESENT ITERATION					
0	0.46017880D 00	-0.88685450D 00	0.41527300D-01	-0.43940000D-03	-0.10504000D-02	-0.40810000D-03
1	0.44073071D 00	-0.89725850D 00	-0.26146131D-01	-0.49398366D-03	-0.10915385D-02	-0.48170783D-03
2	0.41590337D 00	-0.90933997D 00	0.11189524D-01	-0.46590771D-03	-0.11068885D-02	-0.37516651D-03
3	0.41528959D 00	-0.90964373D 00	0.91015700D-02	-0.46784552D-03	-0.11099580D-02	-0.39826711D-03
4	0.41498679D 00	-0.90976048D 00	0.11037467D-01	-0.46698982D-03	-0.11095646D-02	-0.39822039D-03
5	0.41499400D 00	-0.90975719D 00	0.11038137D-01	-0.46699713D-03	-0.11095595D-02	-0.39823060D-03

APPENDIX II-2

INPUT FILE and OUTPUT LISTING for RENDEZVOUS MISSION

```
 1
    TEST CASE NUMBER 2 FOR DOUBLE PRECISION DECK
      RENDEZVOUS , 44 DEGREE PLANE CHANGE (7/8/69)
          APRIL 28,1970
398601.5  12644651. 100.
4551.3088 4719.843  25.057641 5.5990612 -5.4170902-.0118389
.4601788  -.8868545 .0415273  -.0004394 -.0010504 -.0004081
-28954.51430655.047 198.07783 1.6129526 1.5096618 2.1382224 21254.526
 410
934.      0.0       0.0       0.0
2047.6868 0.0       22384.406 92986.438
2302.8677 0.0       0.0       0.0
21032.055 0.0       22384.406 92986.438
21150.852 0.0       0.0       0.0
```

```
CASE NUMBER   1


   TEST CASE NUMBER 2 FOR DOUBLE PRECISION DECK
     RENDEZVOUS , 44 DEGREE PLANE CHANGE (7/8/69)
         APRIL 28,1970

GRAVITATIONAL CONSTANT= 398601.50 INITIAL MASS=  0.12644651D 08 MAX INTEGRATION STEP=   100.000
MAX NUMBER OF ITERATIONS= 10 NUMBER OF SEPERATE ARCS=  4


                                       ATP ARRAY

       TIME                DELTA MASS          MASS RATE             THRUST

     0.93400000D 03       0.0                 0.0                   0.0
     0.20476868D 04       0.0                 0.22384406D 05        0.92986438D 05
     0.23028677D 04       0.0                 0.0                   0.0
     0.21032055D 05       0.0                 0.22384406D 05        0.92986438D 05
     0.21150852D 05       0.0                 0.0                   0.0

INITIAL STATE X0     4551.3088000      4719.8430000       25.0576410        5.5990612       -5.4170902       -0.0118389
   ESTIMATED Q0        0.4601788        -0.8868545        0.0415273        -0.0004394       -0.0010504       -0.0004081

DESIRED FINAL C -0.28954514D 05  0.30655047D 05  0.19807783D 03  0.16129526D 01  0.15096618D 01  0.21382224D 01  0.21254526D 05


ITERATION NUMBER    1

                      COAST ARC
                           LEG= 1 STATE AT END   0.566318D 04 -0.326767D 04 -0.356782D 01 -0.391782D 01 -0.675935D 01 -0.318202D-01
                                COSTATE AT END  -0.722407D 00 -0.129057D 01 -0.323877D 00 -0.114317D-02  0.648871D-03 -0.147330D-03
                                PSY=  0.170086D 00     ALPHA= -0.608892D 02     CALCULATED COAST TIME=  0.111369D 04
                           SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653122D 04 RMAX=  0.656147D 04 ENERGY= -0.304446D 02
                           PERIOD=  0.527119D 04 HMAG=  0.510820D 05 H VECTOR  0.798618D 02  0.194182D 03 -0.510815D 05
                           EMAG=  0.231018D-02 E VECTOR  0.831756D-04 -0.230866D-02 -0.864613D-05 RMAG=  0.653829D 04
                      BURN ARC
                           LEG= 2 STATE AT END   0.426352D 04 -0.504586D 04 -0.745324D 02 -0.717528D 01 -0.721794D 01 -0.583854D 00
                                COSTATE AT END  -0.969137D 00 -0.107410D 01 -0.346046D 00 -0.756952D-03  0.100789D-02 -0.259838D-04
                                MASS AT END OF LEG=  0.693258D 07     NUMBER OF INTEGRATION STEPS IN BURN ARC=   3
                      COAST ARC
                           LEG= 3 STATE AT END  -0.317621D 05  0.259625D 05  0.302587D 02  0.111208D 01  0.119976D 01  0.941503D-01
                                COSTATE AT END  -0.626227D-01 -0.322131D 00  0.158030D 01  0.278217D-04 -0.645883D-05  0 100898D-04
                                PSY=  0.761752D 00     ALPHA= -0.167481D 02     CALCULATED COAST TIME=  0.187292D 05
                           SEMIMAJOR AXIS=  0.237998D 05 RMIN=  0.654658D 04 RMAX=  0.410531D 05 ENERGY= -0.837404D 01
                           PERIOD=  0.365402D 05 HMAG=  0.670907D 05 H VECTOR  0.240808D 04  0.302406D 04 -0.669793D 05
                           EMAG=  0.724932D 00 E VECTOR  0.571934D 00 -0.445440D 00  0.451239D-03 RMAG=  0.410230D 05
                      BURN ARC
                           LEG= 4 STATE AT END  -0.316329D 05  0.260821D 05  0.148941D 03  0.105811D 01  0.780402D 00  0.206199D 01
                                COSTATE AT END  -0.593005D-01 -0.322897D 00  0.158143D 01  0.281100D-04 -0.643979D-05  0 899515D-05
                                MASS AT END OF LEG=  0.427338D 07     NUMBER OF INTEGRATION STEPS IN BURN ARC=   2
                      TARGET VEHICLE FINAL POSITION AND VELOCITY
                           R  -0.291209D 05  0.304977D 05 -0.236038D 02      V   0.159695D 01  0.152651D 01  0.213827D 01
                        TARGET ORBIT SPECIFICATIONS
                           SEMIMAJOR AXIS=  0.421678D 05 RMIN=  0.421677D 05 RMAX=  0.421679D 05 ENERGY= -0.472637D 01
                           PERIOD=  0.861752D 05 HMAG=  0.129646D 06 H VECTOR  0.652483D 05  0.622307D 05 -0.931567D 05
                           EMAG=  0.266008D-05 E VECTOR  0.170160D-05 -0.203762D-05 -0.169346D-06
                        RESULTANT ORBIT SPECIFICATIONS
                           SEMIMAJOR AXIS=  0.296051D 05 RMIN=  0.176883D 05 RMAX=  0.415220D 05 ENERGY= -0.673196D 01
                           PERIOD=  0.506945D 05 HMAG=  0.994416D 05 H VECTOR  0.536647D 05  0.653842D 05 -0.522841D 05
                           EMAG=  0.402527D 00 E VECTOR  0.330948D 00 -0.219758D 00  0.648665D-01 RMAG=  0.409992D 05
                      TOTAL BURN TIME=  0.373978D 03 ARC TIMES   0.111369D 04  0.255181D 03  0 187292D 05  0 119797D 03
```

```
            DC    0.251195D 04  0.441559D 04 -0.172545D 03  0.538835D 00  0.746112D 00  0.762818D-01
                 -0.291278D-03 -0.126512D 00  0.191551D-04  0.0           0.0           0.0
            DETERMINANT OF E= -0.492687D 10 DIAGONAL OF E -0.252892D 05 -0.160285D 04  0.803543D 02  0.590142D 05
             -0.176823D 05 -0.245039D 04 -0.222588D 00 -0.333908D-04 -0.212493D-01  0.374570D-05
            DU=  0.101254D 00 DUDT=  0.165794D 01 CK=  0.100000D 01 FVT=  0.100000D-07
            CK=MIN OF    0.19752D 01  0.36582D 01  0.10000D 01  0.69923D 03  0.25975D 03  0.11923D 02

            CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
             -0.565514D-01 -0.329611D-01 -0.772514D-01 -0.166398D-04 -0.713886D-04 -0.367702D-04
                         0.873701D 02  0.875525D 02  0.123604D 03  0.118622D 03
END OF ITERATION NUMBER   1
           NEW Q0   0.401574D 00 -0.915137D 00 -0.355424D-01 -0.453720D-03 -0.111608D-02 -0.442607D-03
           NEW SWITCH TIMES   0.213506D 04  0.239042D 04  0.211557D 05  0.212695D 05

ITERATION NUMBER   2

         COAST ARC
            LEG= 1 STATE AT END    0.529070D 04 -0.383939D 04 -0.632351D 01 -0.460105D 01 -0.631605D 01 -0.312033D-01
                 COSTATE AT END  -0.106080D 01 -0.133603D 01 -0.374985D 00 -0.134022D-02  0.870025D-03 -0.204363D-04
                 PSY=  0.183450D 00      ALPHA= -0.608892D 02      CALCULATED COAST TIME=  0.120106D 04
            SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653122D 04 RMAX=  0.656147D 04 ENERGY= -0.304446D 02
            PERIOD=  0.527119D 04 HMAG=  0.510820D 05 H VECTOR  0.798618D 02  0.194182D 03 -0.510815D 05
            EMAG=  0.231018D-02 E VECTOR  0.831756D-04 -0.230866D-02 -0.864613D-05 RMAG=  0.653700D 04
         BURN ARC
            LEG= 2 STATE AT END    0.369857D 04 -0.545243D 04 -0.746042D 02 -0.800957D 01 -0.632648D 01 -0.549005D 00
                 COSTATE AT END  -0.135158D 01 -0.105384D 01 -0.362839D 00 -0.897869D-03  0.129670D-02  0.114184D-03
                 MASS AT END OF LEG=  0.692849D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   3
         COAST ARC
            LEG= 3 STATE AT END  -0.287717D 05  0.302228D 05  0.102612D 03  0.118885D 01  0.108231D 01  0.871027D-01
                 COSTATE AT END    0.261560D 00  0.275796D 00  0.179783D 01  0.291824D-04 -0.325724D-04 -0.107309D-04
                 PSY=  0.761312D 00      ALPHA= -0.165123D 02      CALCULATED COAST TIME=  0.187652D 05
            SEMIMAJOR AXIS=  0.241397D 05 RMIN=  0.654735D 04 RMAX=  0.417320D 05 ENERGY= -0.825615D 01
            PERIOD=  0.373256D 05 HMAG=  0.671694D 05 H VECTOR  0.252143D 04  0.262808D 04 -0.670706D 05
            EMAG=  0.728772D 00 E VECTOR  0.506813D 00 -0.523686D 00 -0.146705D-02 RMAG=  0.417282D 05
         BURN ARC
            LEG= 4 STATE AT END  -0.286210D 05  0.303599D 05  0.210473D 03  0.147978D 01  0.134725D 01  0.195011D 01
                 COSTATE AT END    0.264870D 00  0.272081D 00  0.179655D 01  0.289874D-04 -0.327111D-04 -0.118530D-04
                 MASS AT END OF LEG=  0.438081D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   2
         TARGET VEHICLE FINAL POSITION AND VELOCITY
            R  -0.289304D 05  0.306776D 05  0.230041D 03       V    0.161525D 01  0.150722D 01  0.213821D 01
           RESULTANT ORBIT SPECIFICATIONS
            SEMIMAJOR AXIS=  0.352788D 05 RMIN=  0.288256D 05 RMAX=  0.417319D 05 ENERGY= -0.564931D 01
            PERIOD=  0.659448D 05 HMAG=  0.116583D 06 H VECTOR  0.589215D 05  0.561255D 05 -0.834856D 05
            EMAG=  0.182918D 00 E VECTOR  0.129191D 00 -0.129428D 00  0.416719D-02 RMAG=  0.417245D 05
         TOTAL BURN TIME=  0.369178D 03 ARC TIMES   0.120106D 04  0.255363D 03  0.187652D 05  0.113815D 03

            DC   -0.309362D 03  0.317683D 03  0.195678D 02  0.135471D 00  0.159980D 00  0.188098D 00
                  0.176786D-04 -0.857154D-01 -0.224461D-04  0.0           0.0           0.0
            DETERMINANT OF E=  0.345157D 10 DIAGONAL OF E -0.207878D 05 -0.145524D 04  0.618760D 02 -0.850652D 05
             -0.824959D 04 -0.225935D 04 -0.300208D 00  0.144148D-03  0.528743D-02  0.508284D-05
            DU=  0.555362D-01 DUDT=  0.102966D 01 CK=  0.100000D 01 EVT=  0.100000D-07
            CK=MIN OF    0.36013D 01  0.59249D 01  0.10000D 01  0.12304D 05  0.24180D 03  0.50947D 01

            CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
               0.177390D-01  0.575240D-02  0.523117D-01 -0.176409D-04  0.774860D-05  0.468245D-04
                         0.107927D 02  0.108031D 02 -0.280006D 02 -0.168308D 02
END OF ITERATION NUMBER   2
           NEW Q0   0.418668D 00 -0.907985D 00  0.167435D-01 -0.470636D-03 -0.110663D-02 -0.395174D-03
           NEW SWITCH TIMES   0.214585D 04  0.240122D 04  0.211277D 05  0.212526D 05
```

```
ITERATION NUMBER    3

                                  COAST ARC
                                         LEG= 1 STATE AT END    0.524060D 04 -0.390723D 04 -0.665974D 01 -0.468215D 01 -0 625640D 01 -0 311033D-01
                                                COSTATE AT END  -0.104918D 01 -0.130487D 01 -0.328919D 00 -0.130332D-02  0.885114D-03 -0.704827D-04
                                                PSY=  0.185101D 00      ALPHA= -0.608892D 02      CALCULATED COAST TIME=  0.121185D 04
                                         SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653122D 04 RMAX=  0.656147D 04 ENERGY= -0.304446D 02
                                         PERIOD=  0.527119D 04 HMAG=  0.510820D 05 H VECTOR  0.798618D 02  0.194182D 03 -0.510815D 05
                                         EMAG=  0.231018D-02 E VECTOR  0.831756D-04 -0.230866D-02 -0.864613D-05 RMAG=  0.653685D 04
                                  BURN ARC
                                         LEG= 2 STATE AT END    0.362823D 04 -0.550177D 04 -0.695469D 02 -0.808656D 01 -0.623991D 01 -0.506510D 00
                                                COSTATE AT END  -0.133009D 01 -0.102130D 01 -0.331484D 00 -0.859594D-03  0.129238D-02  0.499343D-04
                                                MASS AT END OF LEG=  0.692826D 07     NUMBER OF INTEGRATION STEPS IN BURN ARC=   3
                                  COAST ARC
                                         LEG= 3 STATE AT END  -0.290958D 05  0.304904D 05  0.704041D 02  0.114524D 01  0.110708D 01  0.797194D-01
                                                COSTATE AT END   0.392962D 00  0.353330D 00  0.163520D 01  0.354282D-04 -0.361030D-04  0 143025D-05
                                                PSY=  0.757655D 00      ALPHA= -0.163720D 02      CALCULATED COAST TIME=  0.187264D 05
                                         SEMIMAJOR AXIS=  0.243465D 05 RMIN=  0.654738D 04 RMAX=  0.421457D 05 ENERGY= -0.818600D 01
                                         PERIOD=  0.378065D 05 HMAG=  0.672142D 05 H VECTOR  0.235273D 04  0.240013D 04 -0.671301D 05
                                         EMAG=  0.731076D 00 E VECTOR  0.503439D 00 -0.530113D 00 -0.130912D-02 RMAG=  0.421454D 05
                                  BURN ARC
                                         LEG= 4 STATE AT END  -0.289233D 05  0.306526D 05  0.197156D 03  0.165880D 01  0.152538D 01  0.212397D 01
                                                COSTATE AT END   0.397374D 00  0.348802D 00  0.163531D 01  0.351832D-04 -0.363556D-04  0.341915D-06
                                                MASS AT END OF LEG=  0.413055D 07     NUMBER OF INTEGRATION STEPS IN BURN ARC=   2
                                  TARGET VEHICLE FINAL POSITION AND VELOCITY
                                         R  -0.289575D 05  0.306522D 05  0.194053D 03      V    0.161266D 01  0.150997D 01  0.213822D 01
                                     RESULTANT ORBIT SPECIFICATIONS
                                         SEMIMAJOR AXIS=  0.427401D 05 RMIN=  0.420893D 05 RMAX=  0.433908D 05 ENERGY= -0.466309D 01
                                         PERIOD=  0.879353D 05 HMAG=  0.130508D 06 H VECTOR  0.648045D 05  0.617591D 05 -0.949658D 05
                                         EMAG=  0.152255D-01 E VECTOR -0.622105D-02  0.132014D-01  0.434007D-02 RMAG=  0.421447D 05
                                  TOTAL BURN TIME=  0.380359D 03 ARC TIMES   0.121185D 04  0.255374D 03  0.187264D 05  0.124985D 03

                                         DC  -0.342972D 02 -0.407428D 00 -0.310306D 01 -0.461416D-01 -0.154154D-01  0.142555D-01
                                               -0.157282D-05 -0.905817D-02  0.326442D-05  0.0              0.0              0.0
                                         DETERMINANT OF E=  0.596844D 10 DIAGONAL OF E -0.218607D 05 -0.243782D 04  0.163160D 03 -0.166005D 05
                                          -0.113989D 05 -0.253055D 04 -0.326874D 00 -0.812435D-04 -0.919880D-02  0.586795D-05
                                         DU=  0.689015D-02 DUDT=  0.113840D 00 CK=  0.100000D 01 EVT=  0.100000D-07
                                         CK=MIN OF    0.29027D 02  0.53545D 02  0.10000D 01  0.32418D 04  0.43636D 04  0.33982D 04

                                         CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
                                          -0.363203D-02 -0.177758D-02 -0.557877D-02  0.359956D-05 -0.292653D-05 -0.314151D-05
                                                        -0.294391D 00 -0.255003D 00  0.189075D 01  0.187236D 01
END OF ITERATION NUMBER   3
                           NEW Q0    0.415026D 00 -0.909741D 00  0.111645D-01 -0.467025D-03 -0.110953D-02 -0.398306D-03
                           NEW SWITCH TIMES   0.214556D 04  0.240097D 04  0.211295D 05  0.212545D 05
```

```
ITERATION NUMBER

               COAST ARC
                   LEG= 1 STATE AT END    0.524198D 04 -0.390539D 04 -0.665058D 01 -0.467995D 01 -0.625804D 01 -0.311061D-01
                       COSTATE AT END   -0.105469D 01 -0.131068D 01 -0.332243D 00 -0.130879D-02  0.886090D-03 -0.644332D-04
                       PSY=  0.185056D 00      ALPHA= -0.608892D 02      CALCULATED COAST TIME=  0.121156D 04
                   SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653122D 04 RMAX=  0.656147D 04 ENERGY= -0.304446D 02
                   PERIOD=  0.527119D 04 HMAG=  0.510820D 05 H VECTOR  0.798618D 02  0.194182D 03 -0.510815D 05
                   EMAG=  0.231018D-02 E VECTOR  0.831756D-04 -0.230866D-02 -0.864613D-05 RMAG=  0.653685D 04
               BURN ARC
                   LEG= 2 STATE AT END    0.362975D 04 -0.550059D 04 -0.697346D 02 -0.808575D 01 -0.624167D 01 -0.507672D 00
                       COSTATE AT END   -0.133687D 01 -0.102644D 01 -0.333130D 00 -0.863374D-03  0.129603D-02  0.569163D-04
                       MASS AT END OF LEG=  0.692738D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=    3
               COAST ARC
                   LEG= 3 STATE AT END   -0.291243D 05  0.304936D 05  0.704947D 02  0.114296D 01  0.110832D 01  0.798648D-01
                       COSTATE AT END    0.358181D 00  0.339522D 00  0.164611D 01  0.334510D-04 -0.347154D-04  0.458234D-06
                       PSY=  0.757600D 00      ALPHA= -0.163646D 02      CALCULATED COAST TIME=  0.187286D 05
                   SEMIMAJOR AXIS=  0.243576D 05 RMIN=  0.654736D 04 RMAX=  0.421678D 05 ENERGY= -0.818228D 01
                   PERIOD=  0.378323D 05 HMAG=  0.672165D 05 H VECTOR  0.235724D 04  0.240658D 04 -0.671321D 05
                   EMAG=  0.731198D 00 E VECTOR  0.503537D 00 -0.530188D 00 -0.132549D-02 RMAG=  0.421674D 05
               BURN ARC
                   LEG= 4 STATE AT END   -0.289545D 05  0.306550D 05  0.198022D 03  0.161287D 01  0.150952D 01  0.213770D 01
                       COSTATE AT END    0.362347D 00  0.335170D 00  0.164610D 01  0.332106D-04 -0.349383D-04 -0.635341D-06
                       MASS AT END OF LEG=  0.413008D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=    2
               TARGET VEHICLE FINAL POSITION AND VELOCITY
                   R  -0.289545D 05  0.306550D 05  0.198056D 03       V   0.161295D 01  0.150966D 01  0.213822D 01
                 RESULTANT ORBIT SPECIFICATIONS
                   SEMIMAJOR AXIS=  0.421548D 05 RMIN=  0.421416D 05 RMAX=  0.421679D 05 ENERGY= -0.472784D 01
                   PERIOD=  0.861351D 05 HMAG=  0.129626D 06 H VECTOR  0.652323D 05  0.622156D 05 -0.931500D 05
                   EMAG=  0.312659D-03 E VECTOR  0.223096D-03 -0.218821D-03  0.100806D-04 RMAG=  0.421679D 05
               TOTAL BURN TIME=  0.380380D 03 ARC TIMES   0.121156D 04  0.255413D 03  0.187286D 05  0.124965D 03

                   DC   0.144916D-01  0.445962D-01  0.346548D-01  0.830917D-04  0.140930D-03  0.520975D-03
                      -0.377933D-08 -0.432389D-03  0.520904D-07  0.0             0.0            0.0
                   DETERMINANT OF E=  0.598783D 10 DIAGONAL OF E -0.217546D 05 -0.245682D 04  0.142653D 03 -0.191807D 05
                    -0.113223D 05 -0.251065D 04 -0.325230D 00 -0.901942D-04 -0.828851D-02  0.592425D-05
                   DU=  0.137203D-03 DUDT=  0.174784D-02 CK=  0.100000D 01 EVT=  0.100000D-07
                   CK=MIN OF    0.14577D 04  0.34878D 04  0.10000D 01  0.98475D 05  0.14340D 07  0.24517D 04

                   CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
                    -0.354769D-04 -0.177964D-04 -0.131337D-03  0.308003D-07 -0.333872D-07  0.730410D-07
                                -0.228685D-02 -0.358370D-02 -0.101139D-01  0.153723D-01
END OF ITERATION NUMBER    4
            NEW Q0   0.414991D 00 -0.909759D 00  0.110331D-01 -0.466994D-03 -0.110956D-02 -0.398233D-03
            NEW SWITCH TIMES  0.214555D 04  0.240096D 04  0.211295D 05  0.212545D 05
```

```
ITERATION NUMBER   5

                    COAST ARC
                        LEG= 1 STATE AT END   0.524199D 04 -0.390538D 04 -0.665051D 01 -0.467993D 01 -0.625805D 01 -0.311061D-01
                            COSTATE AT END  -0.105476D 01 -0.131074D 01 -0.332199D 00 -0.130885D-02  0.886103D-03 -0.642700D-04
                            PSY=  0.185056D 00     ALPHA= -0.608892D 02     CALCULATED COAST TIME=  0.121155D 04
                        SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653122D 04 RMAX=  0.656147D 04 ENERGY= -0.304446D 02
                        PERIOD=  0.527119D 04 HMAG=  0.510820D 05 H VECTOR  0.798618D 02  0.194182D 03 -0.510815D 05
                        EMAG=  0.231018D-02 E VECTOR  0.831756D-04 -0.230866D-02 -0.864613D-05 RMAG=  0.653685D 04
                    BURN ARC
                        LEG= 2 STATE AT END   0.362977D 04 -0.550057D 04 -0.697216D 02 -0.808574D 01 -0.624169D 01 -0.507552D 00
                            COSTATE AT END  -0.133695D 01 -0.102649D 01 -0.333047D 00 -0.863428D-03  0.129607D-02  0.570558D-04
                            MASS AT END OF LEG=  0.692741D 07     NUMBER OF INTEGRATION STEPS IN BURN ARC=   3
                    COAST ARC
                        LEG= 3 STATE AT END  -0.291243D 05  0.304936D 05  0.705106D 02  0.114296D 01  0.110833D 01  0.798460D-01
                            COSTATE AT END   0.358079D 00  0.339477D 00  0.164577D 01  0.334458D-04 -0.347118D-04  0.434409D-06
                            PSY=  0.757600D 00     ALPHA= -0.163646D 02     CALCULATED COAST TIME=  0.187286D 05
                        SEMIMAJOR AXIS=  0.243576D 05 RMIN=  0.654736D 04 RMAX=  0.421679D 05 ENERGY= -0.818228D 01
                        PERIOD=  0.378323D 05 HMAG=  0.672165D 05 H VECTOR  0.235665D 04  0.240605D 04 -0.671321D 05
                        EMAG=  0.731198D 00 E VECTOR  0.503537D 00 -0.530189D 00 -0.132577D-02 RMAG=  0.421674D 05
                    BURN ARC
                        LEG= 4 STATE AT END  -0.289545D 05  0.306551D 05  0.198089D 03  0.161295D 01  0.150966D 01  0.213822D 01
                            COSTATE AT END   0.362244D 00  0.335124D 00  0.164576D 01  0.332053D-04 -0.349347D-04 -0.659162D-06
                            MASS AT END OF LEG=  0.412954D 07     NUMBER OF INTEGRATION STEPS IN BURN ARC=   2
                    TARGET VEHICLE FINAL POSITION AND VELOCITY
                        R  -0.289545D 05  0.306551D 05  0.198089D 03     V   0.161295D 01  0.150966D 01  0.213822D 01
                      RESULTANT ORBIT SPECIFICATIONS
                        SEMIMAJOR AXIS=  0.421678D 05 RMIN=  0.421677D 05 RMAX=  0.421679D 05 ENERGY= -0.472637D 01
                        PERIOD=  0.861752D 05 HMAG=  0.129646D 06 H VECTOR  0.652483D 05  0.622307D 05 -0.931567D 05
                        EMAG=  0.271196D-05 E VECTOR  0.171975D-05 -0.208828D-05 -0.190480D-06 RMAG=  0.421679D 05
                    TOTAL BURN TIME=  0.380404D 03 ARC TIMES   0.121155D 04  0.255412D 03  0.187286D 05  0.124992D 03

                        DC  -0.384675D-03  0.317517D-04 -0.196088D-04  0.131628D-06  0.173770D-07 -0.174528D-07
                            0.148425D-10  0.460771D-06 -0.240278D-10  0.0            0.0            0.0
                        DETERMINANT OF E=  0.599584D 10 DIAGONAL OF E -0.217534D 05 -0.245960D 04  0.142443D 03 -0.191803D 05
                         -0.113305D 05 -0.251111D 04 -0.325336D 00 -0.903365D-04 -0.827456D-02  0.592797D-05
                        DU=  0.518046D-07 DUDT=  0.182016D-05 CK=  0.100000D 01 EVT=  0.100000D-07
                        CK=MIN OF   0.38607D 07  0.33492D 07  0.10000D 01  0.78409D 08  0.48664D 10  0.99215D 08

                        CHANGE REQUESTED IN INITIAL COSTATE,SWITCHING TIMES AND FINAL TIME
                          0.342414D-07  0.160488D-07  0.354073D-07 -0.355641D-10  0.243606D-10 -0.785175D-10
                                    0.956533D-06  0.258524D-05  0.660976D-06  0.310746D-07
 END OF ITERATION NUMBER   5
               NEW Q0   0.414991D 00 -0.909759D 00  0.110332D-01 -0.466994D-03 -0.110956D-02 -0.398233D-03
               NEW SWITCH TIMES   0.214555D 04  0.240096D 04  0.211295D 05  0.212545D 05
```

```
ITERATION NUMBER   6

          COAST ARC
               LEG= 1 STATE AT END    0.524199D 04 -0.390538D 04 -0.665051D 01 -0.467993D 01 -0.625805D 01 -0.311061D-01
                      COSTATE AT END  -0.105476D 01 -0.131074D 01 -0.332199D 00 -0.130885D-02  0.886193D-03 -0.642700D-04
                      PSY=  0.185056D 00      ALPHA= -0.608892D 02      CALCULATED COAST TIME=  0.121155D 04
               SEMIMAJOR AXIS=  0.654634D 04 RMIN=  0.653122D 04 RMAX=  0.656147D 04 ENERGY= -0.304446D 02
               PERIOD=  0.527119D 04 HMAG=  0.510820D 05 H VECTOR  0.798618D 02  0.194182D 03 -0.510815D 05
               EMAG=  0.231018D-02 E VECTOR  0.831756D-04 -0.230866D-02 -0.864613D-05 RMAG=  0.653685D 04
          BURN ARC
               LEG= 2 STATE AT END    0.362977D 04 -0.550057D 04 -0.697216D 02 -0.808574D 01 -0.624169D 01 -0.507552D 00
                      COSTATE AT END  -0.133695D 01 -0.102649D 01 -0.333048D 00 -0.863428D-03  0.129607D-02  0.570558D-04
                      MASS AT END OF LEG=  0.692741D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   3
          COAST ARC
               LEG= 3 STATE AT END  -0.291243D 05  0.304936D 05  0.705106D 02  0.114296D 01  0.110833D 01  0.798460D-01
                      COSTATE AT END   0.358079D 00  0.339477D 00  0.164577D 01  0.334458D-04 -0.347118D-04  0.434416D-06
                      PSY=  0.757600D 00      ALPHA= -0.163646D 02      CALCULATED COAST TIME=  0.187286D 05
               SEMIMAJOR AXIS=  0.243576D 05 RMIN=  0.654736D 04 RMAX=  0.421679D 05 ENERGY= -0.818228D 01
               PERIOD=  0.378323D 05 HMAG=  0.672165D 05 H VECTOR  0.235665D 04  0.240605D 04 -0.671321D 05
               EMAG=  0.731198D 00 E VECTOR  0.503537D 00 -0.530189D 00 -0.132577D-02 RMAG=  0.421674D 05
          BURN ARC
               LEG= 4 STATE AT END  -0.289545D 05  0.306551D 05  0.198089D 03  0.161295D 01  0.150966D 01  0.213822D 01
                      COSTATE AT END   0.362245D 00  0.335125D 00  0.164576D 01  0.332053D-04 -0.349347D-04 -0.659155D-06
                      MASS AT END OF LEG=  0.412954D 07      NUMBER OF INTEGRATION STEPS IN BURN ARC=   2
          TARGET VEHICLE FINAL POSITION AND VELOCITY
               R  -0.289545D 05  0.306551D 05  0.198089D 03      V   0.161295D 01  0.150966D 01  0.213822D 01
            RESULTANT ORBIT SPECIFICATIONS
               SEMIMAJOR AXIS=  0.421678D 05 RMIN=  0.421677D 05 RMAX=  0.421679D 05 ENERGY= -0.472637D 01
               PERIOD=  0.861752D 05 HMAG=  0.129646D 06 H VECTOR  0.652483D 05  0.622307D 05 -0.931567D 05
               EMAG=  0.266009D-05 E VECTOR  0.170161D-05 -0.203764D-05 -0.169356D-06 RMAG=  0.421679D 05
          TOTAL BURN TIME=  0.380404D 03 ARC TIMES   0.121155D 04  0.255412D 03  0.187286D 05  0.124992D 03
```

TEST CASE NUMBER 2 FOR DOUBLE PRECISION DECK
RENDEZVOUS , 44 DEGREE PLANE CHANGE (7/8/69)
APRIL 28,1970

2

SUMMARY TABLES

ITERATION NUMBER	TOTAL BURN TIME	LENGTH OF BURN AND COAST ARCS			
1	0.3739779D 03	0.1113687D 04	0.2551809D 03	0.1872919D 05	0.1187970D 03
2	0.3691784D 03	0.1201057D 04	0.2553634D 03	0.1876524D 05	0.1138150D 03
3	0.3803586D 03	0.1211850D 04	0.2553738D 03	0.1872644D 05	0.1249849D 03
4	0.3803796D 03	0.1211555D 04	0.2554131D 03	0.1872858D 05	0.1249665D 03
5	0.3804038D 03	0.1211553D 04	0.2554118D 03	0.1872857D 05	0.1249920D 03
6	0.3804038D 03	0.1211553D 04	0.2554118D 03	0.1872857D 05	0.1249920D 03

ITERATION NUMBER	ERROR IN BOUNDARY CONDITIONS-DC(1-8)							
1	0.251195D 04	0.441559D 04	-0.172545D 03	0.538835D 00	0.746112D 00	0.762818D-01	-0.291278D-03	-0.126512D 00
2	-0.309362D 03	0.317683D 03	0.195678D 02	0.135471D 00	0.159980D 00	0.188098D 00	0.176786D-04	-0.857154D-01
3	-0.342972D 02	-0.407428D 00	-0.310306D 01	-0.461416D-01	-0.154154D-01	0.142555D-01	-0.157282D-05	-0.905817D-02
4	0.144916D-01	0.445962D-01	0.346548D-01	0.830917D-04	0.140930D-03	0.520975D-03	-0.377933D-08	-0.432389D-03
5	-0.384675D-03	0.317517D-04	-0.196088D-04	0.131628D-06	0.173770D-07	-0.174528D-07	0.148425D-10	0.460771D-06

ITERATION NUMBER	DC (9-12)				DU	DUDT	CK
1	0.1915511D-04	0.0	0.0	0.0	0.1012535D 00	0.1657938D 01	0.1000000D 01
2	-0.2244607D-04	0.0	0.0	0.0	0.5553624D-01	0.1029662D 01	0.1000000D 01
3	0.3264418D-05	0.0	0.0	0.0	0.6890147D-02	0.1138397D 00	0.1000000D 01
4	0.5209039D-07	0.0	0.0	0.0	0.1372028D-03	0.1747843D-02	0.1000000D 01
5	-0.2402782D-10	0.0	0.0	0.0	0.5180462D-07	0.1820162D-05	0.1000000D 01

ITERATION NUMBER	NEW Q0 GENERATED BY PRESENT ITERATION					
0	0.46017880D 00	-0.88685450D 00	0.41527300D-01	-0.43940000D-03	-0.10504000D-02	-0.40810000D-03
1	0.40157417D 00	-0.91513656D 00	-0.35542380D-01	-0.45371994D-03	-0.11160821D-02	-0.44260719D-03
2	0.41866804D 00	-0.90798498D 00	0.16743494D-01	-0.47063562D-03	-0.11066283D-02	-0.39517370D-03
3	0.41502616D 00	-0.90974098D 00	0.11164458D-01	-0.46702498D-03	-0.11095285D-02	-0.39830576D-03
4	0.41499068D 00	-0.90975876D 00	0.11033122D-01	-0.46699417D-03	-0.11095618D-02	-0.39823272D-03
5	0.41499071D 00	-0.90975875D 00	0.11033157D-01	-0.46699421D-03	-0.11095618D-02	-0.39823280D-03